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(54) **EXTERNAL DRUG PUMP**

(75) Inventors: **Yossi Gross**, Moshav Mazor (IL); **Oz Cabiri**, Macabim Reut (IL)

(73) Assignee: **Medimop Medical Projects Ltd.**, Ra'anana (IL)

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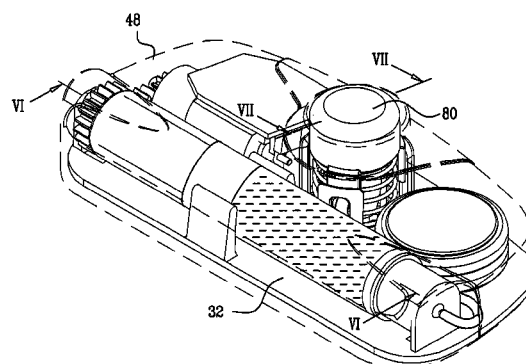
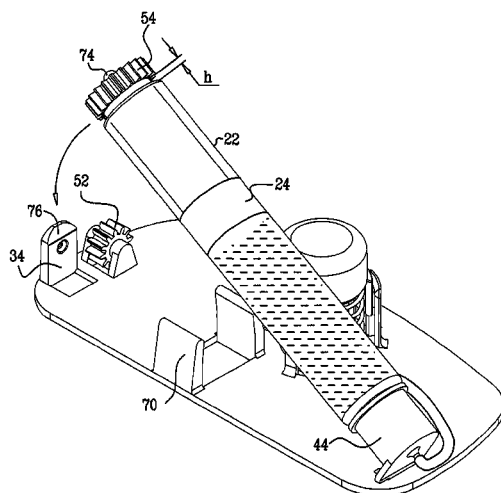
Assistant Examiner — Matthew A Engel

(74) *Attorney, Agent, or Firm* — Panitch Schwarze Belisario & Nadel LLP

(57) **ABSTRACT**

Apparatus is described for administering a substance to a subject. A vial contains the substance and a stopper is disposed within the vial and is slidably coupled to the vial. A first threaded element is (a) rotatable with respect to the vial and (b) substantially immobile proximally with respect to the vial during rotation of the first threaded element. A second threaded element is threadedly coupled to the first threaded element. At least a distal end of the second threaded element is substantially non-rotatable with respect to the vial, and the distal end of the second threaded element defines a coupling portion that couples the second threaded element to the stopper. The first threaded element, by rotating, linearly advances the stopper and at least the distal end of the second threaded element toward a distal end of the vial. Other embodiments are also described.

22 Claims, 12 Drawing Sheets



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FIG. 1A

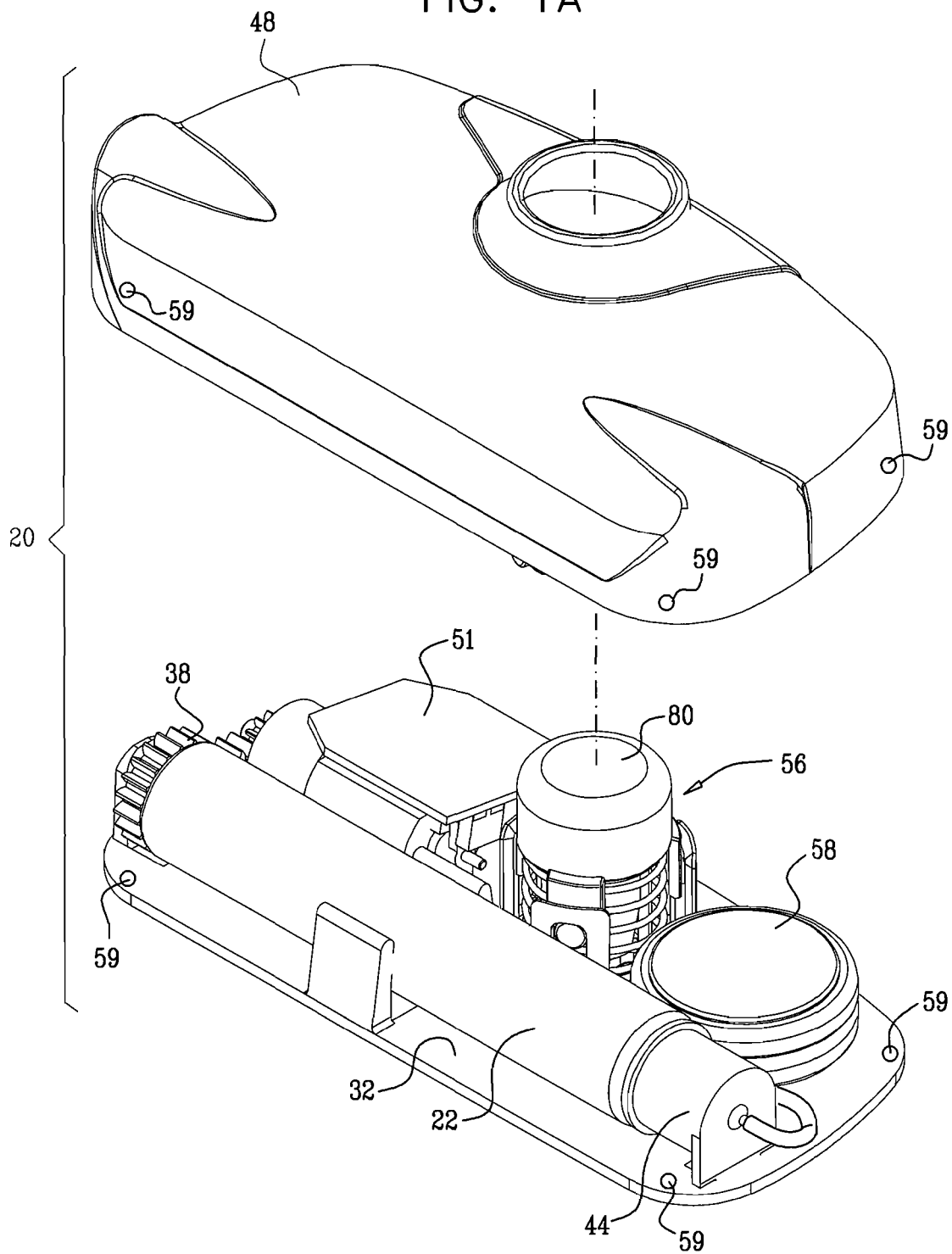
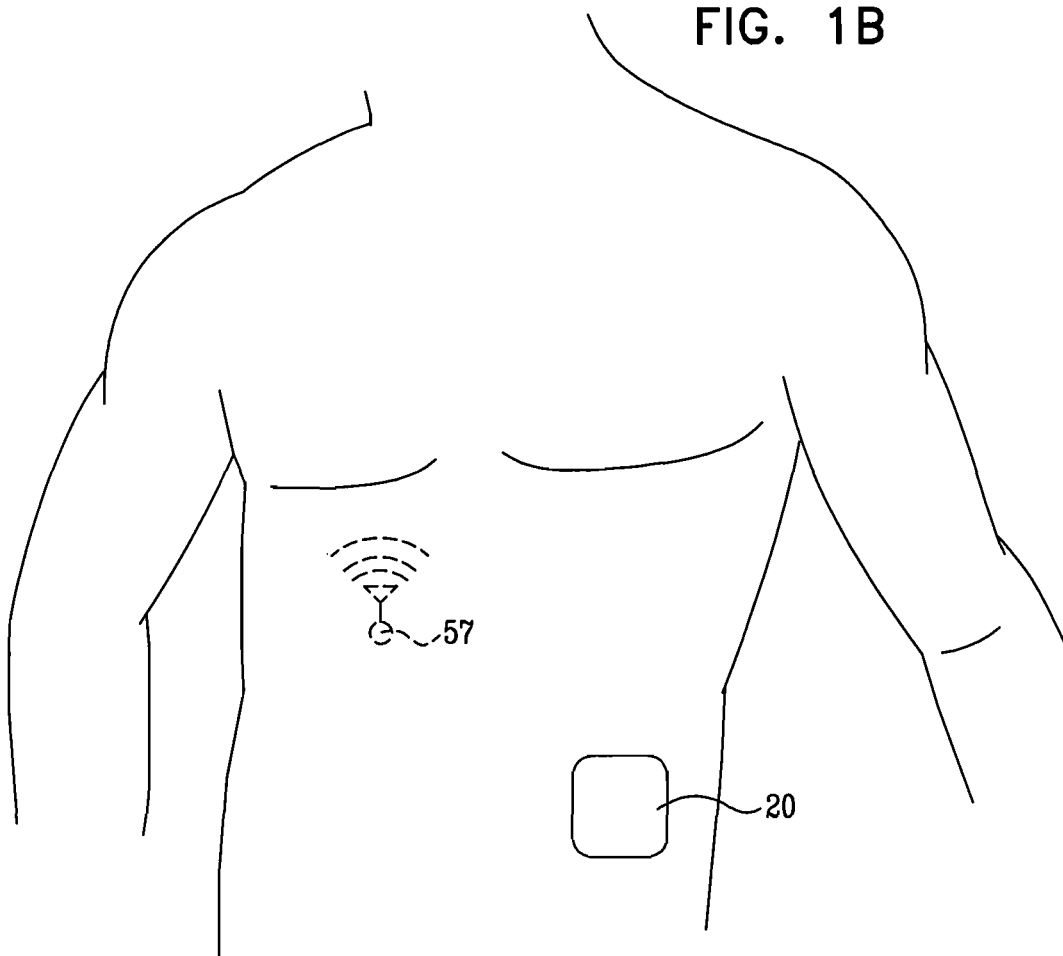
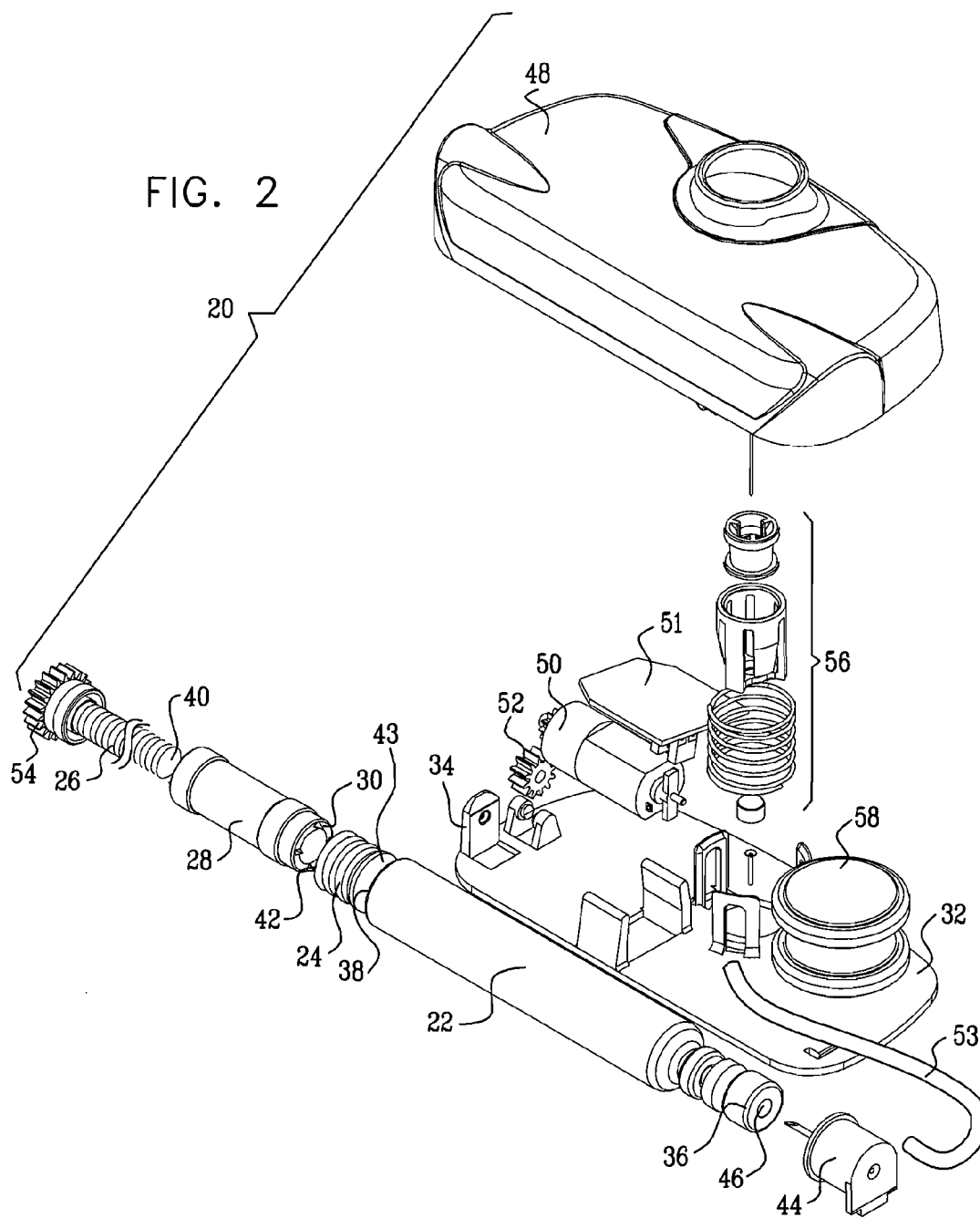


FIG. 1B





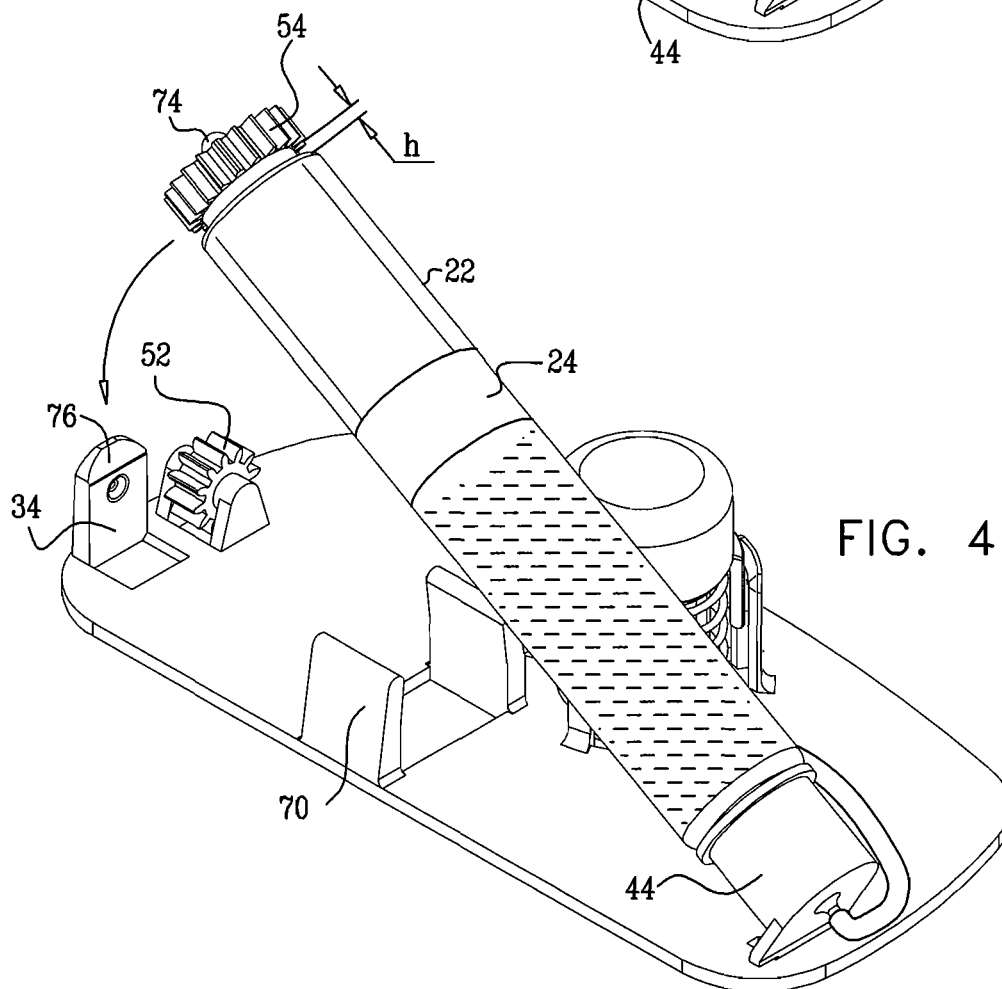
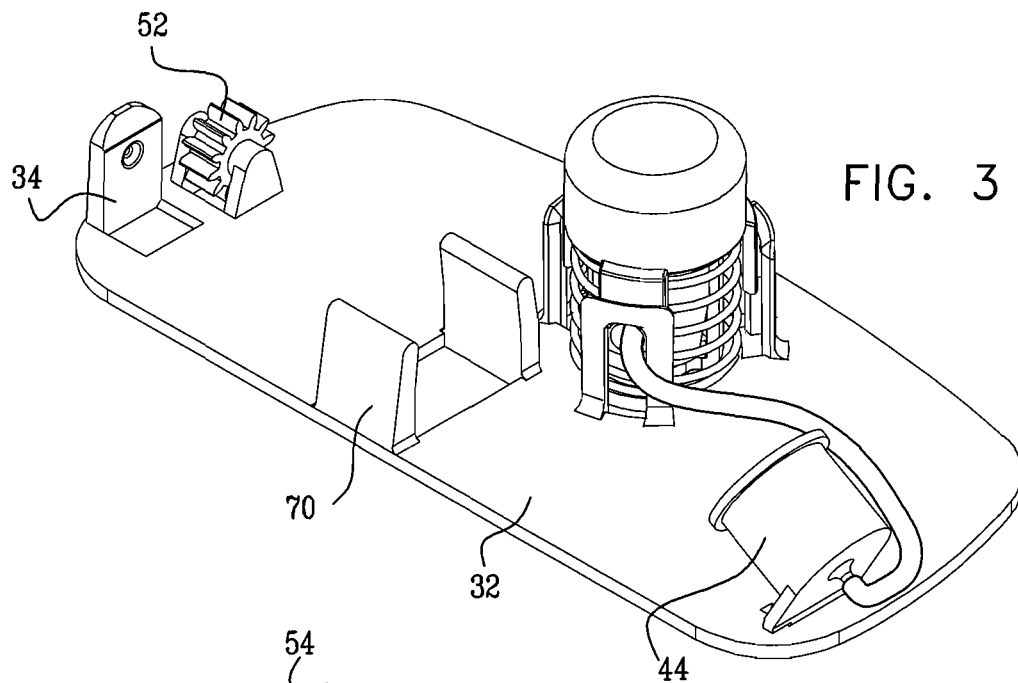


FIG. 5A

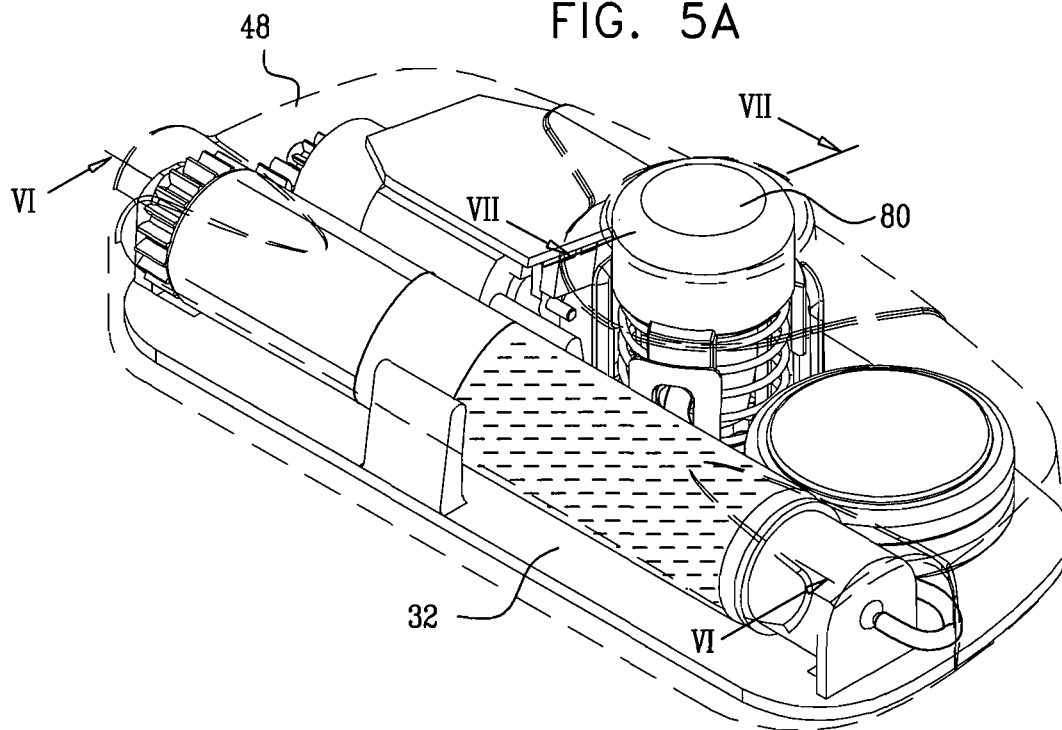
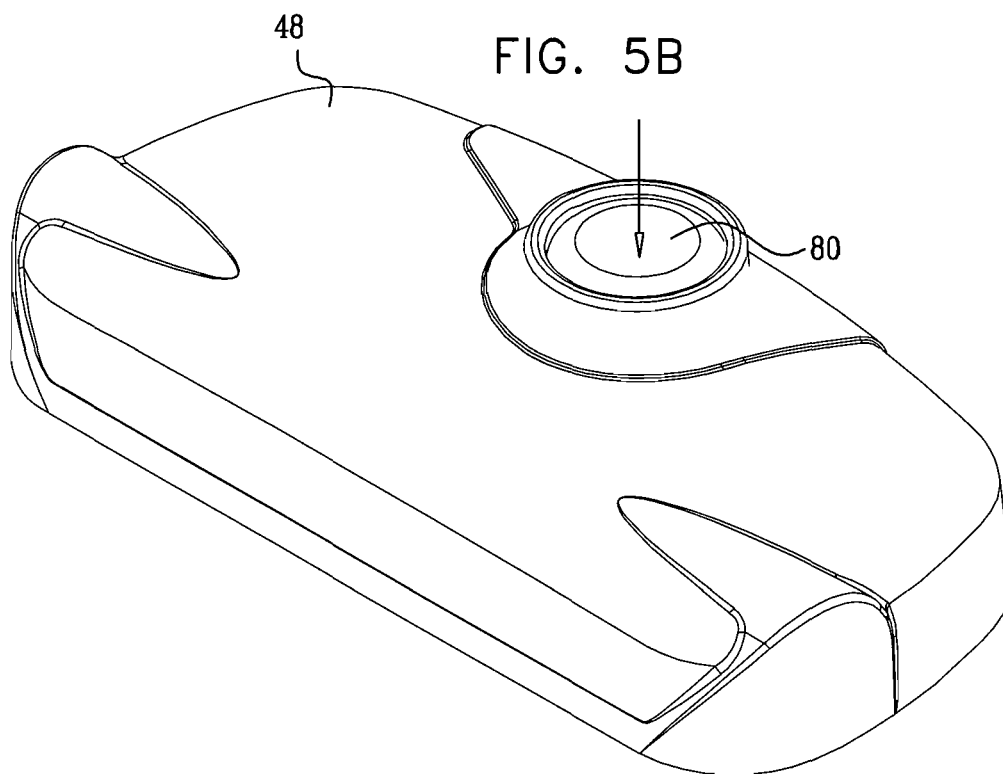
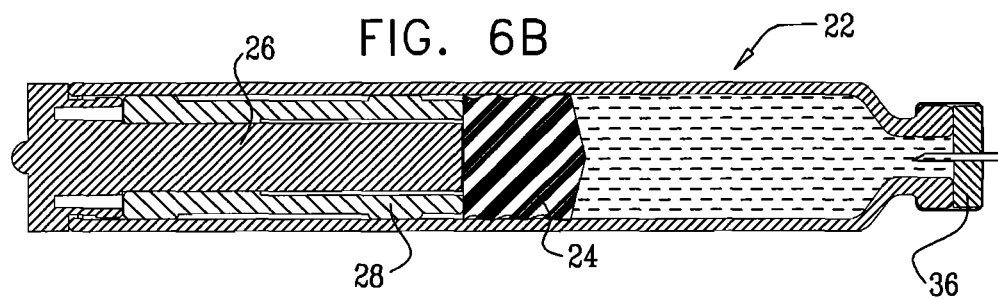
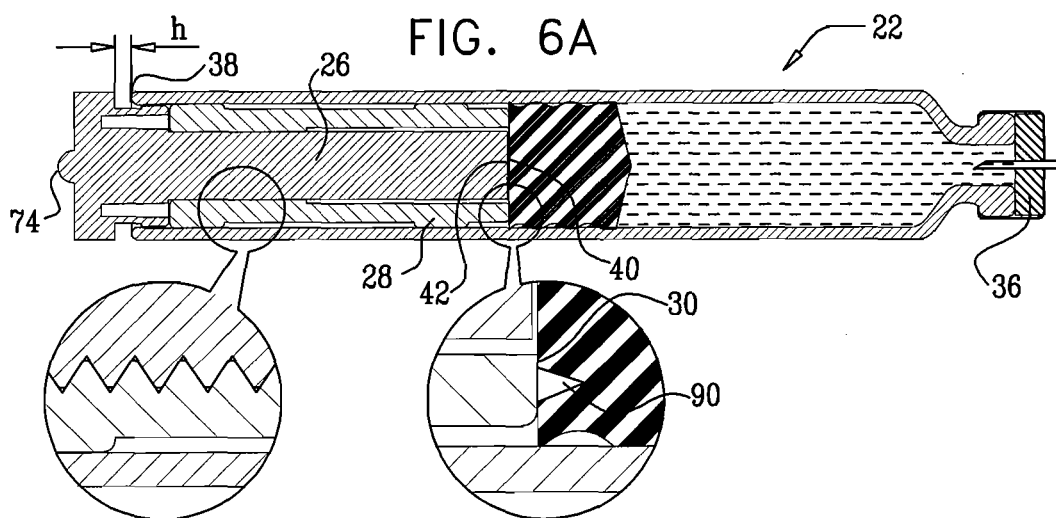
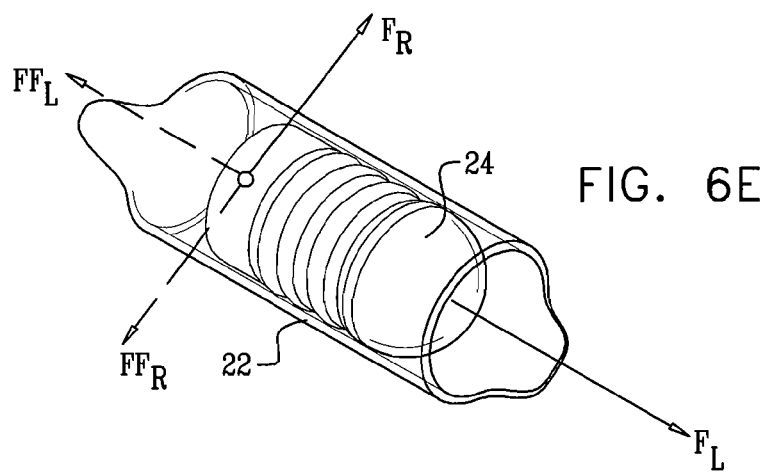
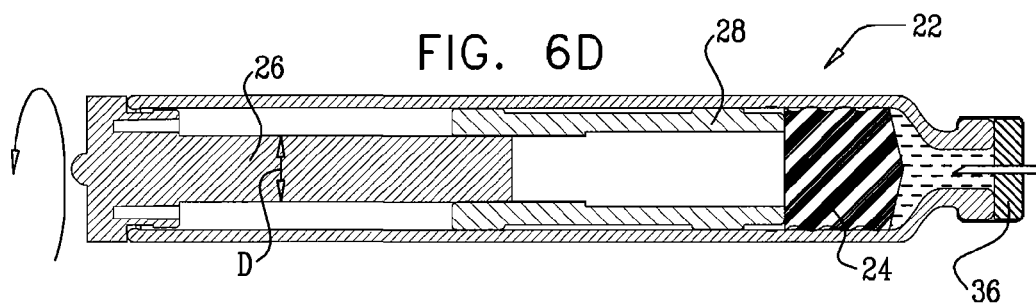
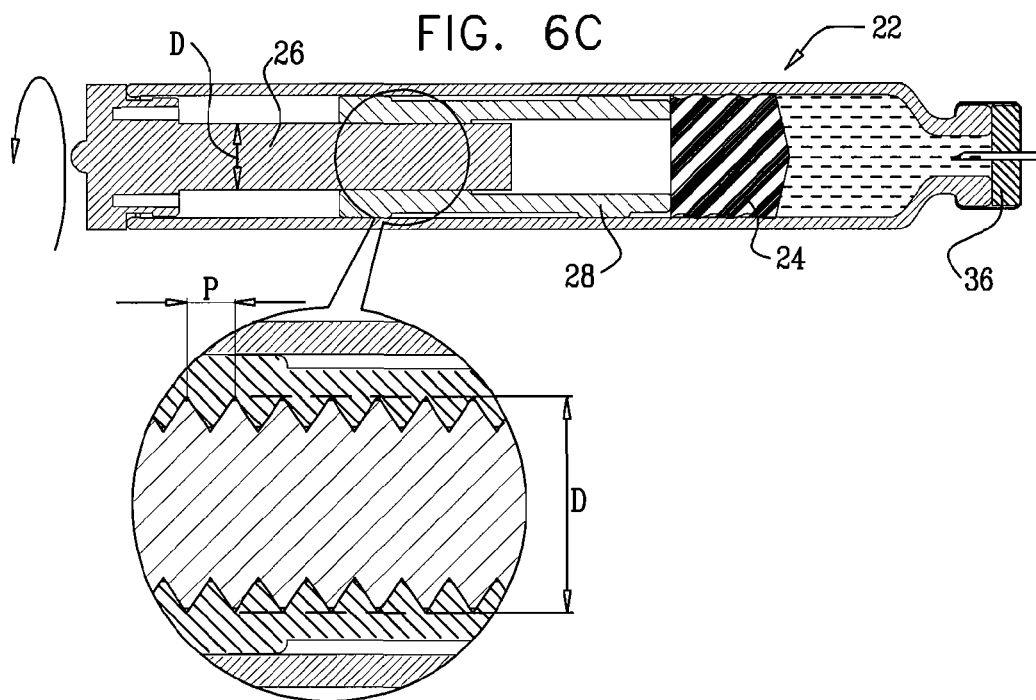
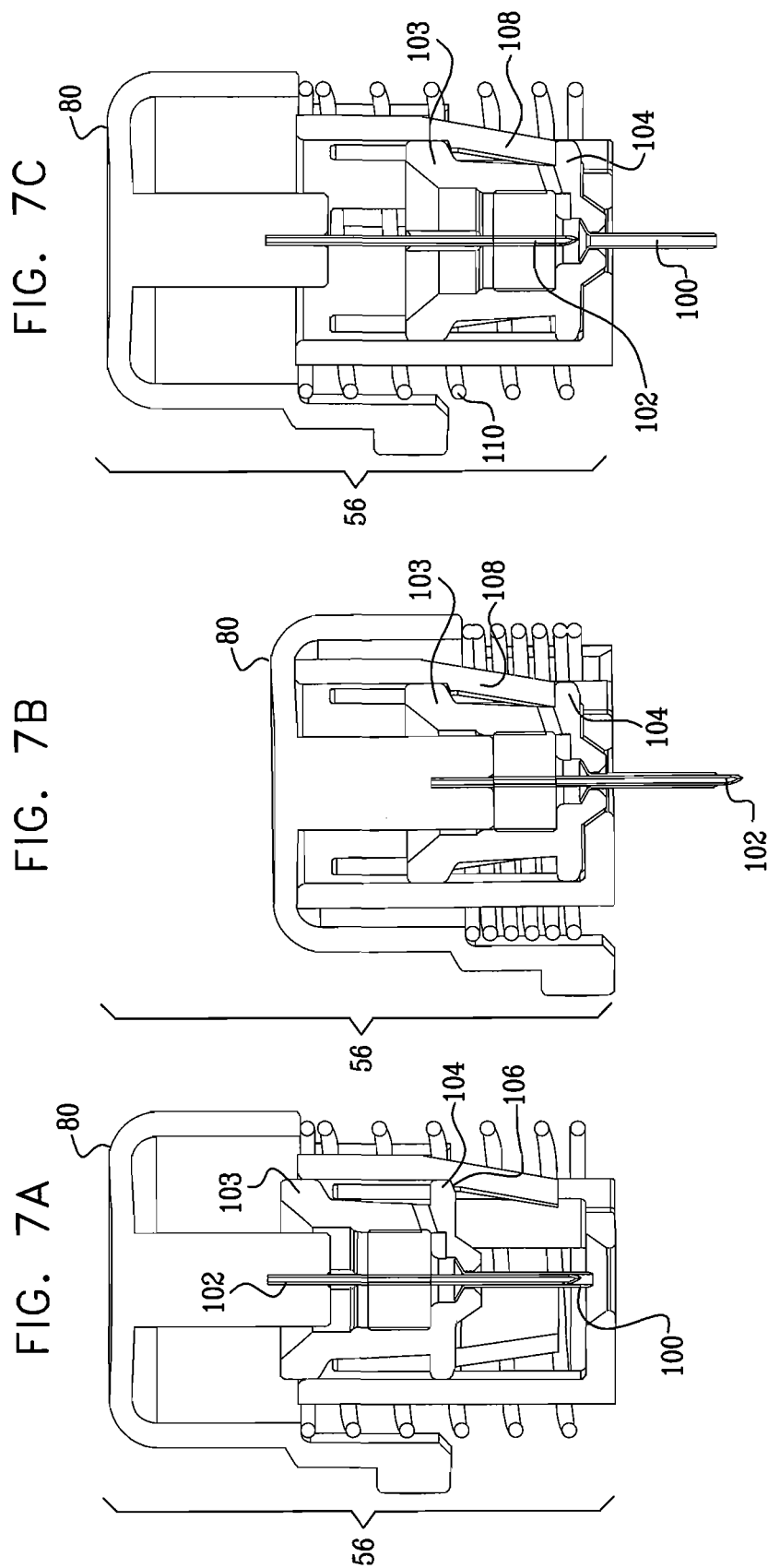


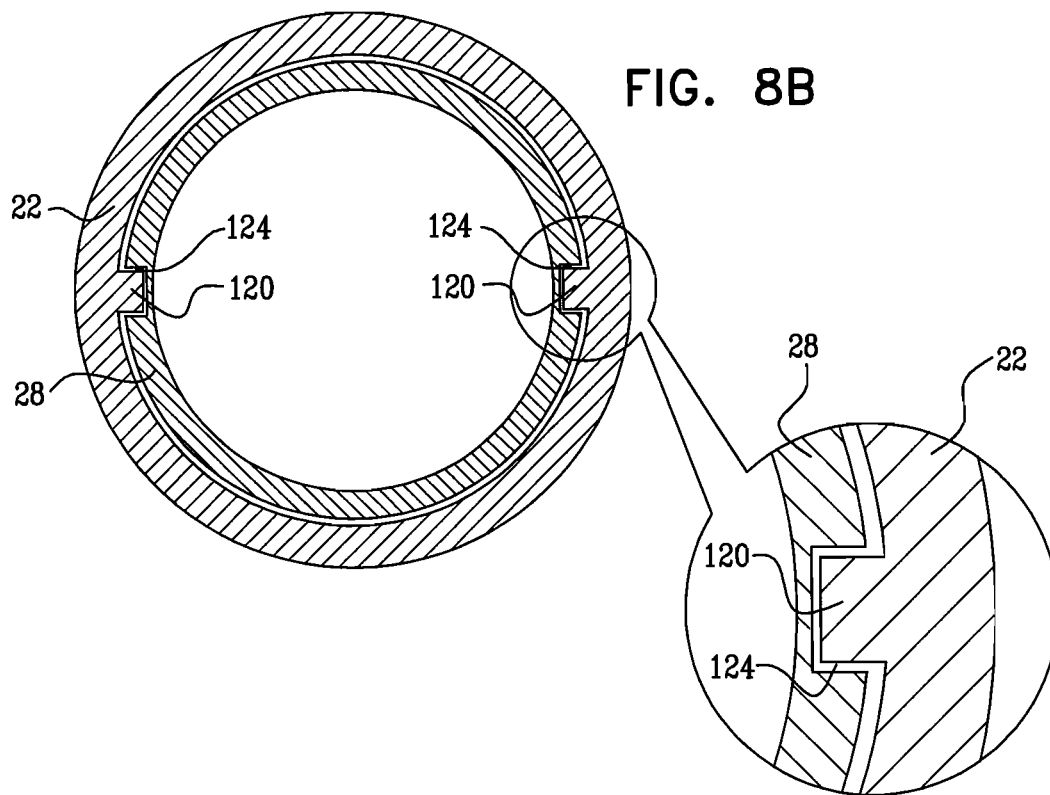
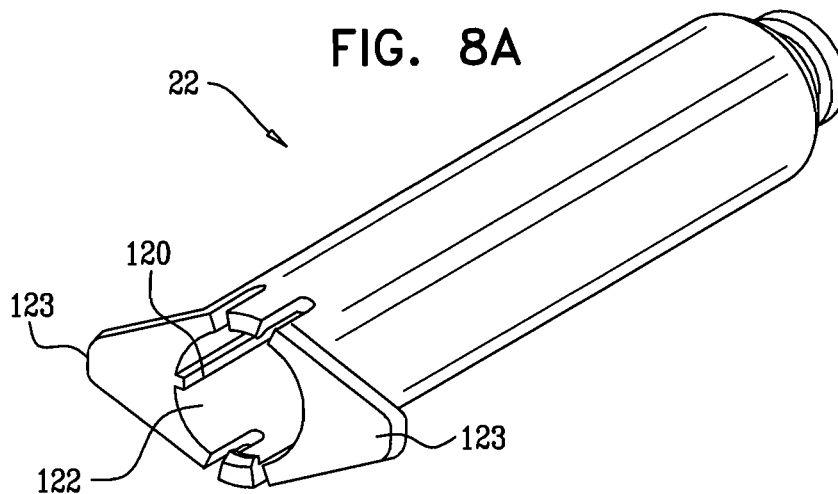
FIG. 5B

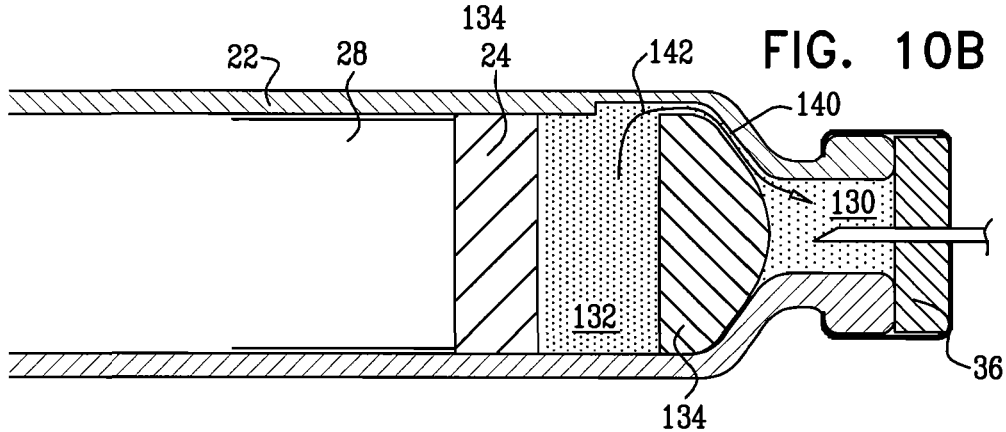
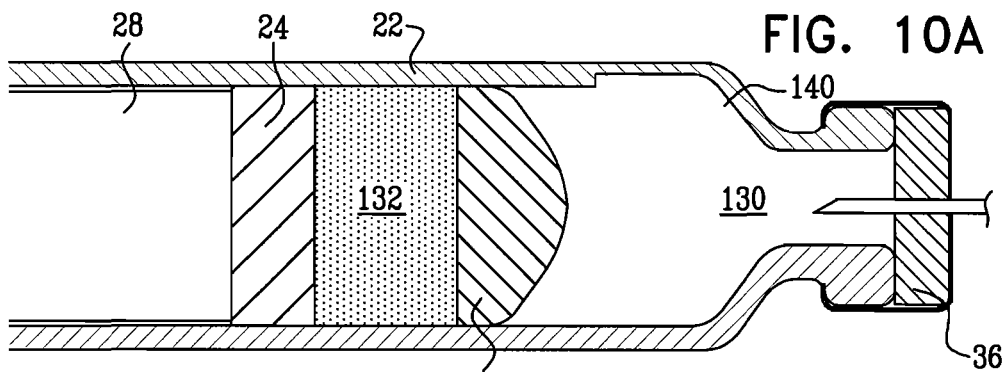
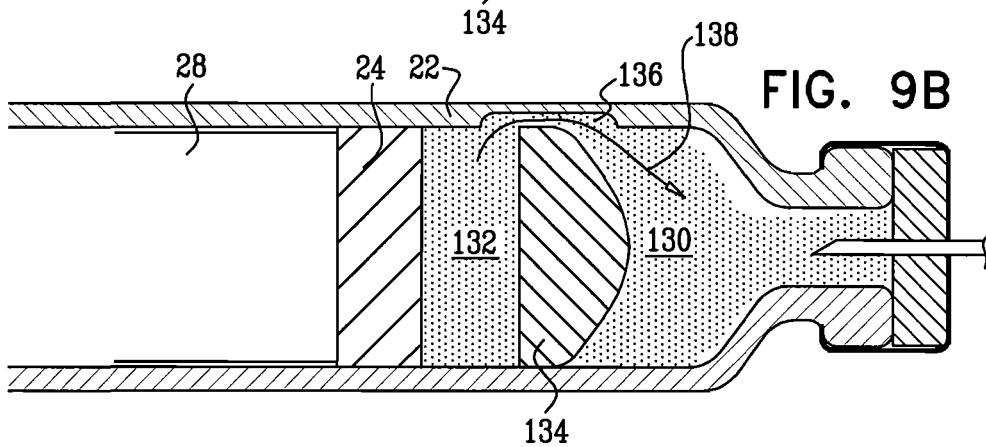
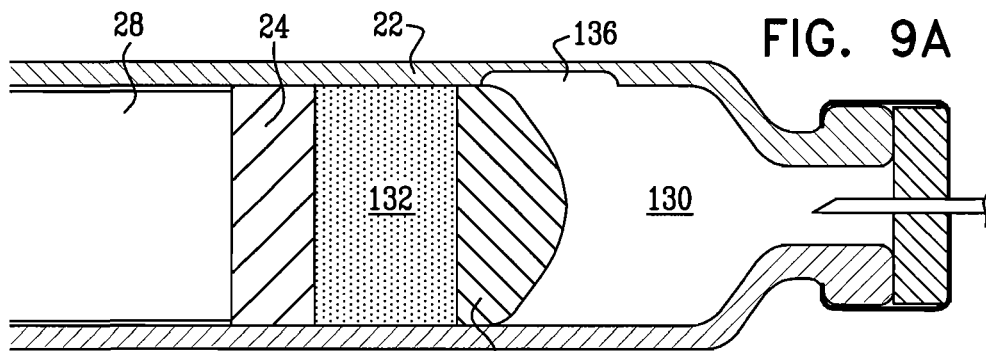


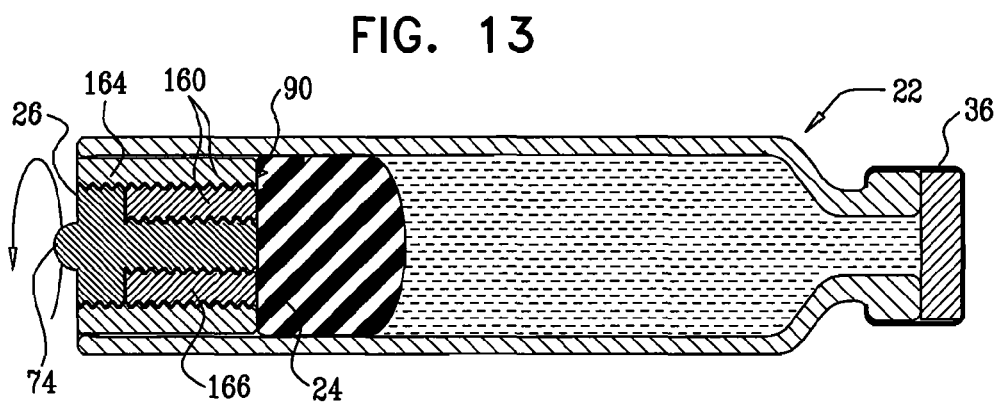
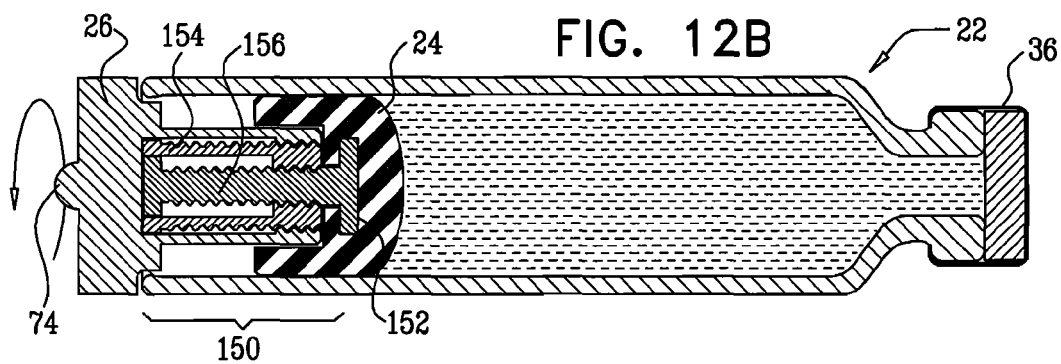
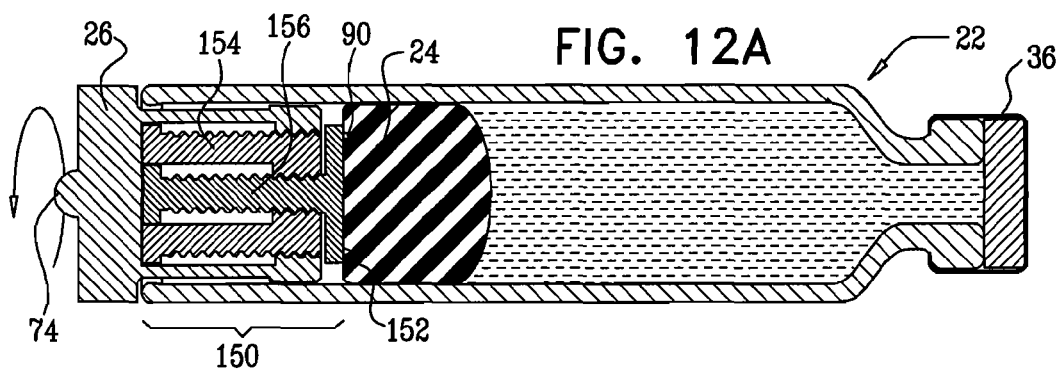
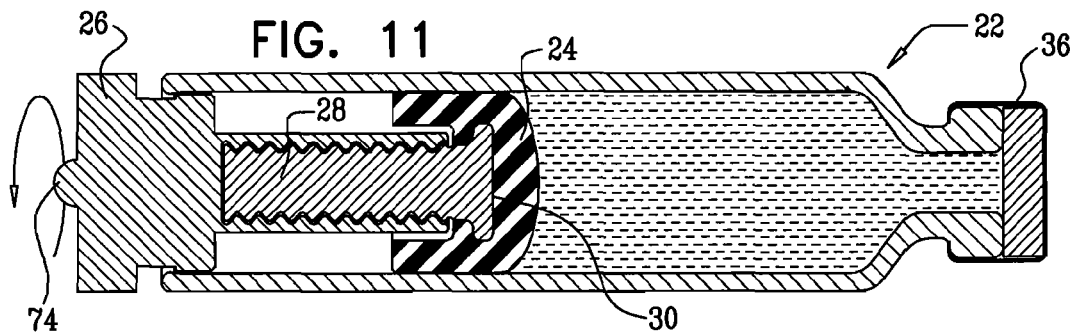


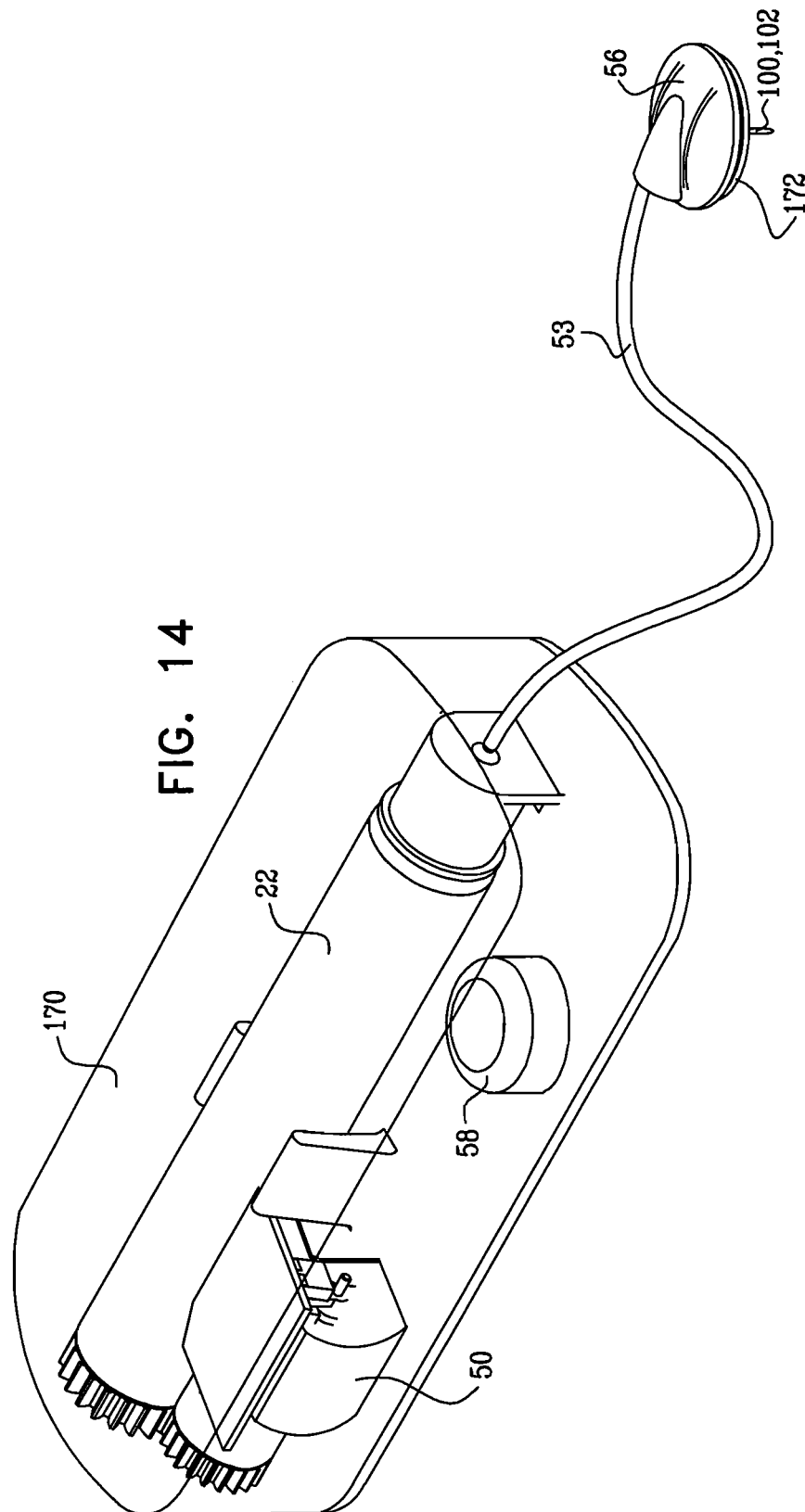












EXTERNAL DRUG PUMP

CROSS-REFERENCES TO RELATED APPLICATIONS

The present application claims the benefit of U.S. Provisional Patent Application 60/997,459 to Gross et al., filed Oct. 2, 2007, entitled, "External drug pump," which is incorporated herein by reference.

The present application is related to a US patent application, entitled, "External drug pump," to Gross et al., filed on even date herewith, which is incorporated herein by reference.

The present application is related to a PCT Application, entitled, "External drug pump," to Gross et al., filed on even date herewith, which is incorporated herein by reference.

FIELD OF THE INVENTION

The present invention generally relates to external medical apparatus. Specifically, the present invention relates to external drug pumps.

BACKGROUND OF THE INVENTION

External drug pumps are typically used to deliver to patients substances which contain large molecules which cannot be digested when administered orally. They are commonly used to infuse a basal rate of insulin to subjects suffering from diabetes, as an alternative to insulin injections by an insulin syringe or an insulin pen. Typically, the pump is adhered to the abdomen of the patient and delivers the substance to the patient via a cannula that is inserted into the patient's skin.

U.S. Pat. No. 6,656,159 to Flaherty, describes a device for delivering fluid, such as insulin for example, to a patient. The device includes an exit port assembly, a syringe-like reservoir including a side wall extending towards an outlet connected to the exit port assembly. A threaded lead screw is received in the reservoir and a plunger has an outer periphery linearly slideable along the side wall of the reservoir and an inner periphery threadedly received on the lead screw. The plunger is non-rotatable with respect to the side wall such that rotating the lead screw is described as causing the plunger to advance within the reservoir and force fluid through the outlet. The device also includes a dispenser having a return element for causing rotation of the lead screw, and a shape memory element. A changeable length of the shape memory element decreasing from an uncharged length to a charged length is described as resetting the return element.

U.S. Pat. No. 6,699,218 to Flaherty, describes a device for delivering fluid to a patient, including a passageway having a proximal fluid transport tube, a distal fluid transport tube, and a tubular expansion member coupling the fluid transport tubes. A penetrating member is positioned within the expansion member for axial movement between the fluid transport tubes, and has a sharpened distal tip. The device also includes a dispenser for causing fluid from a reservoir to flow to the proximal fluid transport tube, a housing containing the dispenser and the passageway and including an exit port receiving the distal fluid transport tube, and a connecting member secured to the penetrating member. The connecting member is movable by a user from an exterior of the housing and arranged such that movement causes the penetrating member to move between an extended position for subcutaneously inserting the distal fluid transport tube into a patient, and a retracted position.

U.S. Pat. No. 6,485,461 to Mason, describes a disposable device which is described as accurately and reliably delivering an infusible liquid to a patient. The infusion device includes a housing which defines a bladder chamber. A compressible bladder is disposed in the bladder chamber and is compressed by the housing upon filling the bladder with an infusible liquid to create a pressurized bladder. The infusion device further includes a delivery system for subcutaneously delivering the infusible liquid to a body. The delivery system includes a collapsible member that supports an injection needle and a cannula. The injection needle is used to insert the cannula into the skin of the body being treated. The cannula is in communication with the bladder during delivery of the infusible liquid. The housing includes microfluidic passageways that allow communication between fluid in the bladder and the cannula.

U.S. Pat. No. 5,851,197 to Marano, describes an injector for automatic placement of a subcutaneous infusion set or the like used for delivering a selected medication to a patient. The injector comprises a spring-loaded plunger having a head for receiving and supporting an infusion set in a position for placement of an insertion needle and related cannula through the skin of a patient at a selected insertion site. The plunger head includes a safety lock mechanism described as engaging and retaining the infusion set during spring-loaded advancement with a controlled force and speed toward the patient's skin to transcutaneously place the insertion needle and cannula. When the plunger head reaches a fully advanced position, with the infusion set placed on the patient, the infusion set is releasable from the safety lock mechanism with minimal force to permit quick and easy separation of the injector.

U.S. Pat. No. 6,960,192 to Flaherty, describes a device for delivering fluid to a person that includes a reservoir for containing a fluid to be delivered to the person; a fluid transport device for dispensing fluid from the reservoir to the person, the fluid transport device including a proximal end in fluid communication with the reservoir and a distal end having a penetrating member for piercing the skin of the person to facilitate the delivery of fluid to the person through the fluid transport device; a housing containing the reservoir and the fluid transport device, the housing including an exit port for receiving the distal end of the fluid transport device upon injection of the distal end into the person and means for securing a first wall of the housing to the skin of the person; and an injection activation device including a driving mechanism contacting the fluid transport device for driving the penetrating member from a first position within the housing, through the exit port to a second position, external to the housing and into the skin of the person.

U.S. Pat. No. 6,905,298 to Haring, describes a nut assembly that will ensure that the shank of a bolt that features a measurable grip length will pass through the contact plane of adjoining members. The nut assembly also allows the desired compressive force in the adjoining members to be attained by using a telescopic feature of the nut to allocate additional thread action for the bolt, enabling the bolt to be drawn into the nut further than what would be allowed by a standard nut. The adaptability of the nut assembly can eliminate the need for washers or shims to adjust the shank penetration of the bolt. The nut assembly is useful for applications in which the specified thread length and the grip length of the bolt is incompatible with the abutment thickness of the adjoining members.

U.S. Pat. No. 1,795,630 to Wilson, describes a screw jack that utilizes a series of telescopic screw threaded sections that may be compactly arranged in the hollow base or housing of

the jack when the jack is not in use, or when only a small space is available in which the jack is to be used.

U.S. Pat. No. 5,643,218 to Lynn et al., describes a syringe for the sequential withdrawal of a first liquid and a second liquid. The syringe has a barrel, a proximal piston moveable along the barrel to define a variable volume chamber intermediate the piston and the end of the barrel, and a distal chamber divider piston for separating the variable volume chamber into primary and secondary reservoirs. A flow channel is defined along the syringe for providing flow connection between the primary and secondary reservoirs. An element links the two pistons so that as the proximal piston is moved away from the distal piston, the first liquid enters the first reservoir and thereafter the second liquid enters the secondary reservoir.

Daikyo Crystal Zenith® polymer, manufactured by Dai-kyo Seiko, Ltd., and used by Dai-kyo Seiko, Ltd. to manufacture vials, is described as being durable, non-flaking, highly transparent, very low in extractable ions, compatible with a wide pH range, and resistant to high heat.

Copaxone® (glatiramer acetate), manufactured by Teva Pharmaceutical Industries Ltd, is a drug described as helping patients who suffer from relapsing-remitting multiple sclerosis.

The following patent and patent application may be of interest:

U.S. Pat. No. 6,749,587 to Flaherty

US Patent Application Publication 2007/0118405 to Campbell

SUMMARY OF THE INVENTION

In some embodiments of the invention, a vial is provided that contains a substance to be administered to a subject. The vial is sealed by a stopper, and has therein first and second threaded elements (e.g., a screw and a nut) that are threadably coupled to each other. The first threaded element is rotatable with respect to the vial, and is linearly immobile with respect to the vial during rotation of the first threaded element. The first threaded element, by rotating, is configured to linearly advance the stopper and at least the distal end of the second threaded element toward the distal end of the vial, without substantially rotating the second threaded element and the stopper. The distal end of the second threaded element defines a coupling portion that couples the second threaded element to the stopper.

In some embodiments, the stopper impedes rotation of the second threaded element, for example, friction between the stopper and the inside of the vial impedes rotation of the second threaded element. Alternatively or additionally, the vial is shaped such that the vial impedes rotation of the second threaded element.

For some applications, the threaded elements are used in conjunction with a standard, commercially-available vial and/or stopper.

Typically, the distal end of the first threaded element is configured to remain proximal to the stopper, or proximal to a distal end of the stopper, and the proximal end of the second threaded element is configured to remain proximal to the distal end of the stopper at all times during the rotating of the first threaded element.

Typically, the apparatus comprises a housing base, the vial and the threaded elements being configured to be inserted into or otherwise coupled to the housing base. For some applications, a portion of the housing base is configured to automati-

cally displace the threaded elements and the stopper toward a distal end of the vial during the insertion into the housing base.

In some embodiments, the subject couples a housing top to the housing base after the vial is inserted into the housing base. The housing top typically contains a motor and a cog, the motor configured to rotate the cog and the cog configured to rotate the first threaded element. For some applications, a control unit administers a basal rate of the substance to the subject by controlling the motor. Alternatively or additionally, the control unit is configured to receive an input and to administer a bolus of the substance to the subject responsively to the input. Further alternatively or additionally, the control unit controls the administering of the substance to the subject in response to the detection by a sensor of one or more physiological parameters of the subject.

For some applications, the substance is administered to the subject via a cannula. Typically, the cannula surrounds a needle. The cannula is inserted into the subject's skin by piercing the subject's skin with the needle and inserting the needle. The needle is typically retracted from the subject's skin following the piercing and the cannula remains inserted in the subject's skin for the duration of the time that the substance is administered to the subject.

In some applications, the apparatus comprises a skin-piercing activation mechanism. Piercing the subject's skin comprises rapidly piercing the subject's skin by displacing a force-receiving element of an activation mechanism. The application of a force to the activation mechanism that exceeds a threshold force displaces the force-receiving element. For example, the subject may press a button coupled to the housing base or top, and, upon application of force that exceeds the threshold force, the needle is suddenly released, and rapidly pierces the skin.

It is noted that the use of two separate portions, the housing top and the housing base, facilitates easier sterilization of components that should be sterilized—particularly the tissue-contacting components of the housing base. The housing top, which typically comprises the battery, motor, and associated electronics, is not typically sterilized.

Additionally, for added convenience of use by the subject, the housing top may be easily removed prior to showering. Alternatively or additionally, all of the components in the housing top are waterproof, such that the housing top may remain coupled to the housing bottom while the subject showers.

In some embodiments, the vial comprises (for example, the vial may be composed of) a cyclic olefin polymer, such as Crystal Zenith®.

There is therefore provided, in accordance with an embodiment of the present invention, apparatus for administering a substance to a subject, including:

- a vial that contains the substance;
- a stopper within the vial, slidably coupled to the vial;
- a first threaded element (a) rotatable with respect to the vial and (b) substantially immobile proximally with respect to the vial during rotation of the first threaded element; and
- a second threaded element that is threadably coupled to the first threaded element,
- at least a distal end of the second threaded element substantially non-rotatable with respect to the vial,
- the distal end of the second threaded element defining a coupling portion that couples the second threaded element to the stopper, and
- the first threaded element, by rotating, linearly advancing the stopper and at least the distal end of the second threaded element toward a distal end of the vial.

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In an embodiment, the apparatus further includes:
a vial housing unit that houses the vial and the threaded elements;

a needle housing unit coupled to the vial housing unit and not rigidly connected to the housing unit;

a needle housed within the needle housing unit; and

a cannula at least partially disposed around the needle, and the apparatus is configured to administer the substance to the subject via the cannula.

In an embodiment, the distal end of the second threaded element is disposed at least partially within the stopper.

In an embodiment, the second threaded element is configured to be coupled to the stopper by a user.

In an embodiment, the second threaded element is provided to a user, the second threaded element already coupled to the stopper.

In an embodiment, the vial includes a circular barrel having an inner surface that is smooth.

In an embodiment, the substance includes insulin and the insulin is disposed within the vial.

In an embodiment, a distal end of the first threaded element remains proximal to a proximal end of the stopper at all times during the rotating of the first threaded element.

In an embodiment,

the apparatus further includes a dividing stopper within the vial, slidably coupled to the vial;

the vial includes a distal compartment and a proximal compartment, the distal compartment containing a powder and the proximal compartment containing a liquid, the dividing stopper reversibly inhibiting fluid communication between the distal compartment and the proximal compartment, and

the first threaded element, by rotating, mixes the powder and the liquid by advancing the dividing stopper toward the distal end of the vial.

In an embodiment, a distal end of the second threaded element is configured to remain proximal to a distal end of the stopper at all times during the rotating of the first threaded element.

In an embodiment, the apparatus further includes a housing base, the vial and the first and second threaded elements are configured to be inserted into the housing base, and a portion of the housing base is configured to impede proximal linear motion of the first threaded element during rotation of the first threaded element.

In an embodiment, the first threaded element includes thread that defines a maximal diameter and a pitch, and a ratio between the maximal diameter and the pitch is 6:1 to 15:1.

In an embodiment, friction between the stopper and an inner surface of the vial impedes rotation of the second threaded element.

In an embodiment, friction between the stopper and an inner surface of the vial impedes rotation of the second threaded element while allowing distal motion of the second threaded element.

In an embodiment, the apparatus further includes a housing base, the vial and the first and second threaded elements are configured to be inserted into the housing base, and a portion of the housing base is configured to displace the threaded elements and the stopper toward the distal end of the vial during the insertion into the housing base.

In an embodiment, the portion of the housing base is configured to apply a sufficient force, in displacing the threaded elements and the stopper, to overcome friction between the stopper and the vial that is due to prolonged storage of the stopper in contact with the vial.

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In an embodiment, the apparatus further includes a cannula coupled to the housing base and configured to be inserted into skin of the subject, and the housing base, by displacing the threaded elements and the stopper, is configured to expel gas through a distal end of the cannula.

In an embodiment, the portion of the housing base, by displacing the threaded elements and the stopper, is configured to expel at least some of the substance through the distal end of the cannula.

In an embodiment, the portion of the housing base is disposed with respect to a portion at a proximal end of the vial such that, during the insertion of the vial and the threaded elements into the housing base, relative motion between the portion of the housing base and the portion at the proximal end of the vial displaces the threaded elements and the stopper toward the distal end of the vial.

In an embodiment, the portion of the housing base is disposed such that sliding motion between the portion of the housing base and the portion at the proximal end of the vial advances the threaded elements and the stopper toward the distal end of the vial.

In an embodiment, the apparatus further includes:

at least one cog that is couplable to a proximal end of the first threaded element and configured to rotate the first threaded element by rotating;

a motor configured to rotate the cog; and

a housing top, to which the cog and the motor are coupled.

In an embodiment, the apparatus further includes a control unit coupled to the motor, and the control unit is configured to receive a coded indication of a characteristic of the substance, and to control the motor in response to the indication of the characteristic of the substance.

In an embodiment, the apparatus further includes a control unit coupled to the motor, and the control unit is programmable and is configured to be programmed to administer a basal rate of the substance to the subject by controlling the motor.

In an embodiment, the apparatus further includes a control unit coupled to the motor, and the control unit is configured to receive an input and to administer a bolus of the substance to the subject responsively to the input.

In an embodiment, the apparatus further includes:

a control unit coupled to the motor; and

a sensor configured to detect a physiological parameter of the subject and to transmit a signal to the control unit responsively to the parameter, and

the control unit is configured to control the motor responsively to the signal.

In an embodiment, the sensor is configured to be implanted in the subject's body.

In an embodiment, the sensor is configured to transmit the signal wirelessly.

In an embodiment, the apparatus further includes a housing base configured to hold the vial, and the housing base and the housing top are configured to be coupled together by the subject prior to the administering of the substance, and decoupled from each other by the subject following the administering of the substance.

In an embodiment,

the housing top is configured to be reused subsequent to the administering of the substance from the vial, and

the housing base and the threaded elements are configured to be discarded subsequent to the administering of the substance from the vial.

In an embodiment, the apparatus further includes:
 one or more magnetic elements coupled to the housing base; and
 one or more magnetic elements coupled to the housing top, and

the magnetic elements are configured to reversibly magnetically couple the housing base to the housing top when the housing base and housing top are aligned.

In an embodiment, the apparatus further includes:

a housing base, and the vial and the threaded elements are configured to be inserted into the housing base;

a needle coupled to the housing base; and

a cannula at least partially disposed around the needle, the needle is configured to pierce skin of the subject and insert the cannula into the subject's skin,

the needle is configured to retract subsequent to piercing, and

the apparatus is configured to administer the substance to the subject via the cannula.

In an embodiment,

the apparatus further includes a needle activation mechanism coupled to the needle, the needle activation mechanism including:

a subject-contact surface for application thereto of a force by the subject; and

a force-receiving element which is configured to be displaced when the force applied by the subject to the subject-contact surface exceeds a threshold force, and the needle is configured to rapidly pierce the skin in response to displacement of the force-receiving element due to the force exceeding the threshold force.

In an embodiment, the apparatus further includes a spring, and the spring is configured to retract the needle subsequent to the piercing.

In an embodiment, the apparatus further includes:

a housing base, the vial and the threaded elements being configured to be inserted into the housing base; and

a needle coupled to the housing base and configured to pierce skin of the subject, and

the apparatus is configured to administer the substance to the subject via the needle.

In an embodiment, the apparatus is configured to administer substantially all of the substance in less than one hour.

In an embodiment, the substance includes glatiramer acetate and the apparatus is configured to deliver the glatiramer acetate to the subject via the needle.

In an embodiment, the apparatus further includes:

a housing base, the vial and the threaded elements being configured to be inserted into the housing base; and

a plurality of microneedles coupled to the housing base and configured to pierce skin of the subject, and

the apparatus is configured to administer the substance to the subject via the plurality of microneedles.

In an embodiment, a diameter of each of the microneedles is less than 150 microns.

In an embodiment, the first threaded element includes a screw, and the second threaded element includes a nut disposed at least partially around the screw.

In an embodiment, the screw includes a telescopic screw, and the screw is configured to advance a distal end of the nut toward the distal end of the vial by extending the telescopic screw toward the distal end of the vial.

In an embodiment, the telescopic screw includes two at least partially overlapping portions.

In an embodiment, the telescopic screw includes three or more at least partially overlapping portions.

In an embodiment, the nut includes a telescopic nut, and the screw is configured to advance a distal end of the nut toward the distal end of the vial by extending the telescopic nut toward the distal end of the vial.

In an embodiment, the telescopic nut includes two at least partially overlapping portions.

In an embodiment, the telescopic nut includes three or more at least partially overlapping portions.

In an embodiment, the first threaded element includes a nut, and the second threaded element includes a screw disposed at least partially inside the nut.

In an embodiment, the screw includes a telescopic screw, and the nut is configured to advance a distal end of the screw toward the distal end of the vial by extending the telescopic screw toward the distal end of the vial.

In an embodiment, the telescopic screw includes two at least partially overlapping portions.

In an embodiment, the telescopic screw includes three or more at least partially overlapping portions.

In an embodiment, the nut includes a telescopic nut, and the nut is configured to advance a distal end of the screw toward the distal end of the vial by extending the telescopic nut toward the distal end of the vial.

In an embodiment, the telescopic nut includes two at least partially overlapping portions.

In an embodiment, the telescopic nut includes three or more at least partially overlapping portions.

There is additionally provided, in accordance with an embodiment of the present invention, a method, including: providing:

a vial that contains a substance, and is sealed by a stopper, and

first and second threaded elements for placement within the vial, the first and second threaded elements being threadedly coupled to each other, a distal end of the second threaded element being for coupling to the stopper;

inserting the vial into a housing base, the threaded elements having been inserted into the vial, and the distal end of the second threaded element having been coupled to the stopper; and

pushing the substance out of the vial by advancing the stopper and at least the distal end of the second threaded element toward a distal end of the vial, the advancing being performed by:

rotating the first threaded element with respect to the vial, impeding proximal linear motion of the first threaded element with respect to the vial during rotation of the first threaded element, and

impeding rotational motion of at least the distal end of the second threaded element with respect to the vial.

There is further provided, in accordance with an embodiment of the present invention, apparatus for administering a substance to a subject, including:

a vial that contains the substance;

a stopper within the vial, slidably coupled to the vial;

a shaft within the vial, a distal portion of the shaft being coupled to the stopper; and

a rotation mechanism disposed proximally to the vial, coupled to the shaft and configured to linearly advance the stopper toward a distal end of the vial by rotating the shaft, and at all times during the rotating of the shaft,

(a) a distal end of the shaft is configured to remain proximal to a distal end of the stopper, and

(b) a proximal end of the shaft is configured to remain distal to a proximal end of the rotation mechanism.

There is additionally provided, in accordance with an embodiment of the present invention, a method, including:

providing a vial that contains a substance, is sealed by a stopper, and has therein a shaft that is coupled to the stopper; inserting the vial into a housing base, a rotation mechanism being coupled to the housing base proximally to the vial; pushing the substance out of the vial by advancing the stopper by rotating the shaft; maintaining a distal end of the shaft proximal to a distal end of the stopper at all times during the rotating of the shaft; and maintaining a proximal end of the shaft distal to a proximal end of the rotation mechanism at all times during the rotating of the shaft.

There is further provided, in accordance with an embodiment of the present invention, apparatus for administering a substance to a subject, including:

a vial that contains the substance;
a stopper within the vial, slidably coupled to the vial;
a first threaded element (a) rotatable with respect to the vial and (b) substantially immobile proximally with respect to the vial during rotation of the first threaded element; and
a second threaded element that is threadedly coupled to the first threaded element,
at least a distal end of the second threaded element substantially non-rotatable with respect to the vial,
the distal end of the second threaded element remaining proximal to a distal end of the stopper at all times during rotation of the first threaded element, and
the first threaded element, by rotating, linearly advancing the stopper and at least the distal end of the second threaded element toward a distal end of the vial.

There is additionally provided, in accordance with an embodiment of the present invention, a method, including: providing:

a vial that contains a substance, and is sealed by a stopper, and
first and second threaded elements for placement within the vial, the first and second threaded elements being threadedly coupled to each other, a distal end of the second threaded element being for coupling to the stopper;

inserting the vial into a housing base, the threaded elements having been inserted into the vial, and the distal end of the second threaded element having been coupled to the stopper;

pushing the substance out of the vial by advancing the stopper and at least the distal end of the second threaded element toward a distal end of the vial, the advancing being performed by:

rotating the first threaded element with respect to the vial, impeding proximal linear motion of the first threaded element with respect to the vial during rotation of the first threaded element, and
impeding rotational motion of at least the distal end of the second threaded element with respect to the vial; and
maintaining the distal end of the second threaded element proximal to a distal end of the stopper at all times during the rotating of the first threaded element.

The present invention will be more fully understood from the following detailed description of embodiments thereof, taken together with the drawings, in which:

BRIEF DESCRIPTION OF THE DRAWINGS

FIG. 1A is a schematic illustration of apparatus for administering a substance to a subject, in accordance with an embodiment of the present invention;

FIG. 1B is a schematic illustration of the apparatus of FIG. 1A on a subject's body, a sensor for use with the apparatus being disposed inside the subject's body, in accordance with an embodiment of the present invention;

FIG. 2 is a schematic exploded view of the apparatus of FIG. 1, in accordance with an embodiment of the present invention;

FIG. 3 is a schematic illustration of a housing base of the apparatus of FIG. 1, in accordance with an embodiment of the present invention;

FIG. 4 is a schematic illustration of a vial being inserted into the housing base of FIG. 3, in accordance with an embodiment of the present invention;

FIG. 5A is a schematic illustration of a vial inserted in the housing base, in accordance with an embodiment of the present invention;

FIG. 5B is a schematic illustration of a housing top coupled to the housing base, in accordance with an embodiment of the present invention;

FIGS. 6A-D are schematic cross-sectional illustrations, taken along line VI of FIG. 5A, of the vial at respective stages of use of the apparatus, in accordance with an embodiment of the present invention;

FIG. 6E is a force vector diagram showing the forces acting on a stopper during operation of the apparatus, in accordance with an embodiment of the present invention;

FIGS. 7A-C are schematic cross-sectional illustrations, taken along line VII of FIG. 5A, of an activation mechanism of the apparatus at respective stages of operation of the apparatus, in accordance with an embodiment of the present invention;

FIGS. 8A-B are schematic illustrations of a vial, in accordance with an embodiment of the present invention;

FIGS. 9A-B are schematic illustrations of a double-chambered vial, in accordance with an embodiment of the present invention;

FIGS. 10A-B are schematic illustrations of a double-chambered vial, in accordance with an alternative embodiment of the present invention;

FIG. 11 is a schematic illustration of a vial, in accordance with an embodiment of the present invention;

FIG. 12A-B are schematic illustrations of a vial containing a telescopic screw, in accordance with respective embodiments of the present invention;

FIG. 13 is a schematic illustration of a vial containing a telescopic nut, in accordance with an embodiment of the present invention; and

FIG. 14 is a schematic illustration of apparatus including a vial housing unit and a separate needle housing unit, in accordance with an embodiment of the present invention.

DETAILED DESCRIPTION OF EMBODIMENTS

Reference is now made to FIGS. 1A-B and 2, which are schematic illustrations of apparatus 20 for administering a substance, for example, insulin, to a subject, in accordance with an embodiment of the present invention. Typically, apparatus 20 comprises a vial 22 that contains the substance to be administered to a subject. Vial 22 is sealed at its proximal end by a stopper 24. A first threaded element 26 (e.g., a screw, as shown) is disposed at least in part within the vial, and a second threaded element 28 (e.g., a nut, as shown) is also disposed within the vial, threadedly coupled to the first threaded element. The distal end of the second threaded element defines a coupling portion 30 that couples the second threaded element to the stopper. The first threaded element is rotated by a rotation mechanism (e.g., motor 50), and by rotating, linearly

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advances the second threaded element and the stopper toward a distal end of the vial, without substantially rotating the second threaded element or the stopper.

In some embodiments, first threaded element **26** is a nut and second threaded element **28** is a screw disposed at least in part inside the nut. The nut is configured to rotate and to cause the screw and the stopper to advance toward a distal end of the vial due to the rotation of the nut. Alternatively, the first threaded element is a first screw and the second threaded element is a second screw. The first screw is configured, by rotating, to advance the second screw and the stopper toward the distal end of the vial. In general, apparatus **20** comprises a first threaded element that rotates, but is substantially immobile linearly during rotation of the first threaded element, and a second threaded element that (a) is substantially non-rotatable, (b) moves linearly toward the distal end of the vial in response to the rotation of the first threaded element, and (c) is coupled to the stopper. The first threaded element is rotated, causing the second threaded element and the stopper to advance distally.

Typically, vial **22** is inserted into a housing base **32**. In some embodiments, portion **34** of the housing base is configured to impede proximal linear motion of first threaded element **26**. (In the context of the present patent application and in the claims, the term “proximal” denotes a position toward an end **38** of the vial. The term “distal” denotes a position toward an end **36** of the vial, out of which the substance is administered to the subject.) In some embodiments, during rotation of first threaded element **26**, stopper **24** is configured to impede rotation of second threaded element **28**. Typically, friction of the stopper against the inside of the vial impedes rotational motion of the stopper, and element **28** being coupled to the stopper is similarly impeded. Thus, as first threaded element **26** is rotated, second threaded element **28** and the stopper advance linearly toward distal end **36** of the vial. In some embodiments, a standard, commercially-available vial and stopper are used as vial **22** and stopper **24**. For some applications, the first and second threaded elements are standard, commercially-available threaded elements, e.g., a standard commercially-available screw and nut. Friction between the stopper and the vial impedes rotation of the stopper, while allowing distal movement of the stopper within the vial, as described in further detail hereinbelow, with reference to FIGS. **6C** and **6E**.

For some applications, rotation of the second threaded element is impeded by other means, for example, as described hereinbelow.

For some applications, the initial position of stopper **24** in vial **22** is in accordance with the amount of the substance that is contained within the vial and that is to be administered to the subject. The lengths of first and second threaded elements **26** and **28** are typically such that when the threaded portions of the elements are maximally overlapping (i.e., fully screwed together), and the elements are disposed within the vial, coupling portion **30** couples the second threaded element to the stopper. For example, the lengths of the screw and the nut, shown in FIG. **2**, are typically such that when the screw is maximally inserted within the nut, and the screw and nut are disposed within the vial, coupling portion **30** of the nut couples the nut to the stopper. For example, if the vial contains a small amount of the substance prior to administering the substance, then stopper is disposed toward distal end **36** of the vial. In such a case, a relatively long screw/nut assembly (or screw/screw assembly) is designated to be disposed within the vial, so that coupling portion **30** couples the nut to the stopper. If, on the other hand, a large volume of the substance is contained within the vial, then a relatively short screw/nut

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assembly (or screw/screw assembly) is typically disposed within the vial. For some applications, screw/nut assemblies (or screw/screw assemblies) are color-coded or otherwise marked to indicate which screw/nut assembly (or screw/screw assembly) is suitable for use with which initial volume of substance.

In an alternative embodiment, first and second threaded elements **26** and **28** are placed in the vial, without being selected based on the initial volume of substance, and the elements are unscrewed from each other a suitable amount in order to facilitate the coupling of coupling portion **30** to the stopper.

Typically, a distal end **40** of the first threaded element **26** is configured to remain proximal to the stopper, or proximal to distal end **43** of the stopper, at all times during the rotating of the first threaded element. Further typically, the distal end of the second threaded element remains proximal to the distal end of the stopper at all times during the rotation of the first threaded element. The stopper typically provides a seal between a first portion of the vial, which is distal to the stopper, and a second portion of the vial, which is proximal to the stopper. In some embodiments, the sterility of the substance disposed in the first portion is maintained by the stopper providing a seal between the first portion and the second portion, threaded elements being disposed in the second portion. The first and second threaded elements assembly may be viewed as a shaft that converts the rotational motion of motor **50** to distal advancement of stopper **24**. Typically, at all times during the rotating of the shaft, (a) the distal end of the shaft (i.e., the distal end of the second threaded element) is configured to remain proximal to a distal end of the stopper, and (b) the proximal end of the shaft (i.e., the proximal end of the first threaded element) is configured to remain distal to a proximal end of the rotation mechanism.

For some applications, a vial piercing mechanism **44** is movably (e.g., rotatably) coupled to housing base **32**. As part of the insertion of vial **22** into the housing base, a seal **46** at distal end **36** of the vial is pierced by pressing the seal against the piercing mechanism. The substance is configured to subsequently flow through a tube **53** toward an activation mechanism **56**, which is typically coupled to the housing base, and is configured to insert a cannula and/or a needle through the subject's skin and to deliver the substance via the cannula and/or the needle.

Although first and second threaded elements **26** and **28** have been described as being within vial **22** (e.g., the apparatus may be bought by the subject with the threaded elements already within the vial), in some embodiments, the threaded elements are inserted into the vial and are coupled to stopper **24** by the subject and/or by a healthcare provider. In some embodiments, vial **22** and stopper **24** are a standard, commercially-available vial and stopper, for example, the vial may be a circular barrel with a smooth inner wall. The first and second threaded elements are inserted into the vial and coupled to the stopper, and the apparatus dispenses the substance, in accordance with the techniques described hereinabove. The friction between the standard stopper and the standard vial prevent the second threaded element from rotating due to the coupling of the second threaded element to the stopper, as described hereinabove. For some applications, providing the apparatus described herein for use with standard, commercially-available vials and stoppers provides a commercial advantage.

For some applications, the threaded elements are coupled to housing base **32**, and the subject and/or a healthcare provider moves the vial with respect to the housing base in order to couple the stopper to the second threaded element. For

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example, a standard, commercially-available vial and stopper may be moved with respect to the housing base, in order to couple the stopper to the second threaded element, the threaded elements being coupled to the housing base.

In some embodiments, a housing top **48** is coupled by the subject to housing base **32**. The housing top typically comprises a motor **50** and a battery **58**. (In an embodiment, the battery is coupled to housing base **32**.) For some applications, a first cog **52** is coupled to housing base **32**. The motor is configured to rotate the cog, and the cog is configured to rotate first threaded element **26**. Typically, first cog **52** engages a second cog **54**, the second cog being coupled to the proximal end of threaded element **26**, and/or comprising the proximal portion of threaded element **26**. In some embodiments, only a single cog is used, the single cog being coupled to and/or comprising a proximal portion of threaded element **26**, and the single cog being rotated directly by the motor. Alternatively or additionally, other techniques known in the art are used for converting motion from a motor to rotational or linear motion.

For some applications, the subject reversibly couples the housing top to housing base **32**. Following the termination of the delivery of the substance to the subject from vial **22**, the subject and/or a healthcare provider decouples the housing top from the housing base. In some embodiments, the housing top is configured to be re-used with another housing base, and the housing base is configured to be discarded after a single use. For some applications, the housing top and the housing base comprise magnetic materials **59** that are configured to releasably couple the housing top to the housing base when the top and the base are aligned.

For some applications, a control unit **51** is coupled to motor **50**. In some embodiments, the control unit administers a basal rate of the substance to the subject by controlling the motor. Alternatively or additionally, the control unit is configured to receive an input and to administer a bolus of the substance to the subject responsively to the input. For example, housing top **48** may comprise two buttons. When both buttons are pressed at the same time, the control unit is configured to administer a bolus of the drug. Alternatively, a button **80** associated with activation mechanism **56** may be configured to cause the control unit to administer a bolus of the drug, when pushed subsequent to the insertion mechanism having been activated. Further alternatively or additionally, a sensor **57** (shown in FIG. 1B) is configured to detect one or more physiological parameters of the subject. The control unit is configured to control the administering of the substance in response to the detected parameters. In some embodiments, the sensor is configured to be implanted in the subject. For some applications, the sensor transmits the detected parameters to the control unit wirelessly.

In some embodiments, vial **22** has a distal compartment which contains a powder, and a proximal compartment which contains a liquid. The distal compartment and the proximal compartment are reversibly separated by a dividing stopper **134** (shown in FIGS. 9A-B). First threaded element **26**, by rotating, causes the powder and the liquid to mix by advancing the dividing stopper toward distal end **36** of the vial, as described in detail hereinbelow, with reference to FIGS. 9A-B.

Reference is now made to FIGS. 3 and 4, which are respectively a schematic illustration of housing base **32**, and a schematic illustration of vial **22** being inserted into the housing base, in accordance with an embodiment of the present invention. The housing base, as shown in FIG. 3, is prepared for the insertion of vial **22**. The distal end of the vial is inserted into vial piercing mechanism **44**, which pierces the seal at the

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distal end of the vial. The vial is then lowered into the housing base. Typically, opposing resilient arms **70** support the vial upon the housing base.

In some embodiments, as vial **22** is lowered into housing base **32**, first cog **52** engages second cog **54**. For some applications, as the vial is lowered, portion **34** of the housing base automatically displaces first and second threaded elements **26** and **28** (and therefore stopper **24**) toward distal end **36** of the vial. In some embodiments, the stopper is disposed within the vial such that before the insertion of the vial into the housing, first threaded element **26** protrudes a distance *h* from the proximal end of the vial. The proximal end of the first threaded element (or of second cog **54**) comprises a rounded portion **74**. Portion **34** of the housing base comprises an angled face **76**. As rounded portion **74** slides past the angled face, the first threaded element is pushed the distance *h* inside the vial. As a result, the threaded elements and the stopper are displaced toward the distal end of the vial.

In some embodiments, apparatus **20** comprises alternative means of pushing threaded elements **26** and **28** inside vial **22** during the insertion of the vial into housing base **32**. For example, the proximal end of first threaded element **26** may comprise an angled face and portion **34** of the housing base may comprise a rounded portion. Alternatively, both the proximal end of the first threaded element and portion **34** of the housing may comprise an angled face and/or a rounded portion.

For some applications, portion **34** of housing base **32** is configured to apply a sufficient force, in displacing threaded elements **26** and **28** and stopper **24**, to overcome friction between stopper **24** and vial **22** that is due to prolonged storage of the stopper in contact with the vial. For example, the stopper may have been stored in contact with the inner surface of the vial for a period of at least one week or longer, as a result of which the stopper may have a higher effective static friction than would have existed if the stopper had been recently moved with respect to the vial. Alternatively or additionally, apparatus **20** comprises a cannula **100** and/or a needle **102** (as shown in FIGS. 7A-C), configured to be inserted in the subject's skin. Portion **34** of the housing base, by displacing the threaded elements and the stopper, is configured to expel gas through a distal end of the cannula and/or needle. In some embodiments, in addition to expelling the gas, portion **34** is configured to expel at least some of the substance therefrom, as a result of displacing the threaded elements and the stopper. Typically, the expelling of the substance from the distal end of the cannula before the cannula is inserted into the subject's skin increases the accuracy of the first dosage administered, because the initial activation of the motor essentially immediately administers the substance, without previously ejecting gas stored in the vial or conduits of apparatus **20**.

Reference is now made to FIGS. 5A and 5B, which are respectively a schematic illustration of vial **22** inserted in housing base **32**, and of housing top **48** coupled to housing base **32**, in accordance with an embodiment of the present invention. Housing top **48** is shaped such that when it is coupled to the housing base, button **80** of activation mechanism **56** is accessible to be pressed by the subject.

Reference is now made to FIGS. 6A-E. FIGS. 6A-D are schematic cross-sectional illustrations of vial **22** at respective stages of use of apparatus **20**, in accordance with an embodiment of the present invention. FIG. 6E is a force vector diagram showing the forces acting on stopper **24** during rotation of first threaded element **26**, in accordance with an embodiment of the present invention.

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FIG. 6A shows vial 22 before its insertion into housing base 32. First threaded element 26 (e.g., a screw, as shown) protrudes by distance h from proximal end 38 of the vial. Second threaded element 28 (e.g., a nut, as shown) is threadedly coupled to the first threaded element and is coupled to stopper 24 via coupling portion 30. For example, coupling portion 30 may be shaped to define teeth 90, which are inserted into the stopper. Or, coupling portion 30 may be a flat surface that is flush with a proximal end 42 of stopper 24, or that is otherwise in contact with the stopper.

During insertion of the vial into the housing base, the first and second threaded elements and the stopper are displaced toward distal end 36 of the vial, as shown in FIG. 6B.

First threaded element 26 rotates during administration of the substance to the subject. Rotational motion of second threaded element 28 is impeded (even if not necessarily eliminated) by stopper 24 to which the second threaded element is coupled, and/or rotational motion of the second threaded element is impeded by alternative means, for example, as described with reference to FIGS. 8A-B. Additionally, proximal linear motion of the first threaded element with respect to the vial is impeded (by portion 34 of housing base 32, not shown) during rotation of the first threaded element. The rotation of the first threaded element combined with the impeded rotation of the second threaded element results in the second threaded element and the stopper advancing toward distal end 36 of vial 22, as shown in FIGS. 6C and 6D.

Typically, due to the rotation of the first threaded element, a linear force FL and a rotational force FR act on stopper 24, as shown in FIG. 6E. A linear friction force FFL between the stopper and vial 22 acts to oppose the linear advancement of the stopper, and a rotational friction force FFR between the stopper and the vial acts to oppose rotation of the stopper. Further typically, and as described in detail in the following paragraphs, friction between the stopper and the vial acts to oppose rotation of the stopper to a greater extent than it acts to oppose linear advancement of the stopper through the vial. In particular, in this embodiment, rotation of the stopper by (for example) a full rotation is impeded to a much greater extent than forward motion of the stopper by the pitch of the threaded elements is impeded, because significantly more friction must be overcome to produce a full rotation of the stopper than would need to be overcome in order for the stopper to advance the distance of the pitch of the threaded elements. As a result, friction generally acts to impede rotation of the stopper, while allowing distal movement of the stopper within the vial.

In a more detailed analysis of this effect, it is noted that, in some embodiments, friction between the stopper and the vial has the aforementioned effect due to selection of a suitable ratio of (a) the maximal diameter D of the first threaded element (shown in FIG. 6C) to (b) the pitch P of the first threaded element. Typically, the ratio of the maximal diameter D to the pitch P is 3:1 to 30:1, for example, 6:1 to 20:1, or 8:1 to 15:1. In some embodiments, the ratio is 6:1 to 15:1, for example, 10:1. The pitch of the second threaded element is equal to the pitch of the first threaded element. Proximal linear motion of the first threaded element is impeded (as described hereinabove). Therefore, when the first threaded element rotates and the second threaded element unscrews from the first threaded element, the second threaded element must either rotate, advance distally, or both rotate and advance distally.

By way of example, the first threaded element may have a maximal diameter of 8 mm and a pitch of 1 mm (i.e., a ratio of maximal diameter to pitch of 8:1). Accordingly, the outer perimeter of the first threaded element is greater than 25 mm

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(pi multiplied by the maximal diameter). As the first threaded element rotates through 360 degrees, if the second threaded element were to unscrew from the first threaded element by rotating, the second threaded element would rotate through a distance of more than 25 mm, around the perimeter of the first threaded element. Accordingly, the outer surface of the stopper would rotate in contact with the inner surface of the vial through an even greater distance, such as 40 mm (since the outer diameter of the stopper is greater than that of the first threaded element, as seen, for example, in any of FIGS. 6A-D). Alternatively, if the second threaded element unscrews from the first threaded element by advancing linearly through the vial, it advances by a distance of 1 mm, i.e., by a distance that is equal to the pitch of the threaded elements. Accordingly, in the presence of significant, intentionally-generated friction, the stopper advances substantially only linearly (in contact with the inner surface of the vial) by a distance of 1 mm, while rotating only to a relatively small extent.

It is noted that in some embodiments, friction between the stopper and the vial acts to impede rotation of the stopper, while allowing distal movement of the stopper within the vial, generally irrespective of the ratio of the maximal diameter D to the pitch P of the first threaded element.

As disclosed hereinabove, in some embodiments, friction acts to impede rotation of the stopper, while allowing distal movement of the stopper within the vial, even when the apparatus disclosed herein is used in conjunction with standard, commercially-available vials, stoppers, and threaded elements.

Reference is now made to FIGS. 7A-C, which are schematic illustrations of activation mechanism 56 of apparatus 20 at respective stages of operation of the apparatus, in accordance with an embodiment of the present invention. Typically, following the insertion of vial 22 into housing base 32, and the coupling of housing top 48 to the housing base, the bottom surface of the housing base is adhered to the subject's skin (e.g., with an adhesive), as shown in FIG. 1B. Subsequently, the activation mechanism is activated.

FIG. 7A shows activation mechanism 56 before the activation mechanism has been activated. Needle 102 is disposed within the activation mechanism, and cannula 100 is disposed around the outside of the needle. When the bottom surface of housing base 32 is adhered to the subject's skin, the subject pushes button 80, which is accessible through housing top, as shown in FIG. 5B. Until the force of the pushing of the button exceeds a threshold force, friction between a protrusion 104 of a structural element 103 and force receiving element 106 prevents the button and the needle being pushed down. (Force receiving element 106 is typically a surface of a holding portion 108, described hereinbelow.) When the button is pushed by the subject with a force that exceeds the threshold force, force receiving element 106 is suddenly and rapidly pushed aside by protrusion 104. Typically, by applying sufficient force to the button to overcome the resistive force of force receiving element 106, the subject applies a level of force which is sufficient to suddenly and rapidly insert the needle and cannula into the subject's skin. FIG. 7B shows the needle and cannula having been advanced due to button 80 having been pushed with a force that exceeds the threshold force.

The pushing of button 80 with sufficient force causes structural element 103 to advance toward the subject's skin. When the structural element arrives at the end of its travel, it is held in place by holding portion 108. For example, a proximal portion of protrusion 104 may be secured by a distally-directed force applied thereto by a distal portion of force receiv-

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ing element **106**, constituting holding portion **108**, as shown in FIG. 7B. When the subject releases button **80**, as shown in FIG. 7C, a spring **110** pushes the button up, which retracts needle **102** back inside housing base **32**. Cannula **100** is coupled to structural element **103**, which is held in place by holding portion **108**. Therefore, the cannula remains inserted in the patient's skin. The substance is administered to the subject via the cannula.

In an alternative embodiment, the substance is administered to the subject via needle **102**, the needle remaining inserted in the subject's skin for the duration of the administration. In such an embodiment, apparatus **20** is typically configured to administer substantially all of the substance to the subject in less than one hour. For example, Copaxone® (or another drug) may be administered to the subject in this manner over the course of approximately one half hour.

In some embodiments, needle **102** comprises a plurality of microneedles, which are inserted into the subject's skin, and the substance is administered to the subject via the microneedles. Typically, the diameter of each of the microneedles is about 50-150 microns, e.g., about 100 microns, and the length of each of the microneedles is about 200-1000 microns.

In an embodiment, control unit **51** is configured to receive an indication, on vial **22**, first threaded element **26**, second threaded element **28**, or another element, that indicates a characteristic of the contents of vial **22**. For example, a barcode, RFID, mechanical code, or other code may indicate to the control unit the type of pharmaceutical product in the vial, the quantity of the substance, or a dosage schedule for administration of the substance. Typically, when the subject first receives the vial, stopper **24** is already in place within the vial at the correct position for initiating delivery of the substance.

Reference is now made to FIGS. 8A-B, which are schematic illustrations of respective views of vial **22**, in accordance with an embodiment of the present invention. For some applications, a protrusion **120** protrudes from inner surface **122** of the vial, and second threaded element **28** is a nut that is shaped to define a groove **124** on its outer surface. As the nut advances toward the distal end of the vial, groove **124** slides along protrusion **120**, preventing the nut from rotating. Alternatively or additionally, stopper **24** is shaped to define a groove on its outer surface, the groove preventing the stopper, and therefore the second threaded element, from rotating. In some embodiments, inner surface **122** of vial **22** is not round, but, for example, is square, oval, or rectangular. The outer surface of the second threaded element, and/or the stopper, is shaped similarly to the inner surface of the vial. The shapes of inner surface **122**, and the outer surface of the second threaded element and/or the stopper, prevent the second threaded element from rotating.

In some embodiments, vial **22** contains (for example, the vial may be composed of) a cyclic olefin polymer, such as Crystal Zenith®. In some embodiments, manufacturing the vial using a cyclic olefin polymer facilitates the molding of protrusion **120**. For some applications, stopper **24** is coated with a fluoropolymer. Typically, using a vial that contains a cyclic olefin polymer, and/or a stopper that is coated with a fluoropolymer maintains the stability of a substance that is disposed within the vial. For example, the vial may be used to administer a monoclonal antibody to the subject, and the composition of the vial, the stopper, and/or the second threaded element may maintain the stability of the monoclonal antibody.

In some embodiments, the proximal end of vial **22** is shaped to define two or more flanges **123**. Typically, the flanges facilitate the filling of the vial. For example, during the filling of the vial, the vial may be placed inside a hole of

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a tray, and the flanges may support the vial inside the hole. In some embodiments, the flanges are configured to hold the vial in a fixed position inside housing base **32**.

Reference is now made to FIGS. 9A-B, which are schematic illustrations of vial **22**, in accordance with an embodiment of the present invention. In some embodiments, the vial contains a distal compartment **130**, and a proximal compartment **132**, a dividing stopper **134** inhibiting fluid communication between the proximal and distal compartments. In some embodiments, a powder (for example, medication that is in the form of a powder) is disposed in distal compartment **130** and a liquid (e.g. water, saline, and/or a medication) is disposed in proximal compartment **132**. As second threaded element **28** is advanced distally through the vial, dividing stopper **134** is advanced distally. The advancement of the dividing stopper exposes compartment **132** to conduit **136**. As second threaded element **28** is further advanced, stopper **24** causes the liquid to flow into distal compartment **130** via the conduit, in the direction of arrow **138** (as shown in FIG. 9B). The liquid and the powder then mix and, for example, may form a solution or a suspension, before being administered to the subject. In some embodiments, a first liquid medication is disposed in distal compartment **130** and a second liquid medication is disposed in proximal compartment **132**. Dividing stopper **134** inhibits fluid communication between the first and second medications. As second threaded element **28** advances through the vial, the two medications mix before being administered to the subject.

Reference is now made to FIGS. 10A-B, which are schematic illustrations of vial **22**, in accordance with an embodiment of the present invention. The vial contains a distal compartment **130**, and a proximal compartment **132**, dividing stopper **134** inhibiting fluid communication between the proximal and distal compartments. In some embodiments, a medication is disposed in the distal compartment, and a flushing solution, such as water or saline, is disposed in the proximal compartment. As second threaded element **28** is advanced distally through the vial, dividing stopper **134** is advanced distally, thereby administering to the subject the medication disposed in proximal compartment **130**. When dividing stopper **134** is advanced to a position toward distal end **36** of the vial the flushing solution flows through conduit **140** (in the direction of arrow **142**) and flushes the medication from the vial and/or from conduits of apparatus **20**.

It is noted that the term "providing" as used herein in the specification and in the claims, in the context of providing apparatus (for example, providing a vial), includes within its scope the apparatus being provided by the user of the apparatus, and is not limited to the sale of the apparatus.

Reference is now made to FIG. 11, which is a schematic illustration of vial **22**, in accordance with an embodiment of the present invention. In some embodiments, first threaded element **26** is a nut that is rotatable with respect to vial **22**. Second threaded element **28** is a screw that is threadedly coupled to the nut and disposed at least partially within the nut. During rotation of the nut, linear motion of the nut with respect to the vial is impeded (for example, by portion **34** of housing base **32**, shown in FIG. 4). During rotation of the nut, the screw is substantially rotationally immobile with respect to the vial. Typically, the distal end of the screw is coupled to stopper **24** via coupling surface **30**, and the stopper impedes rotation of the screw. Thus, during rotation of the nut, the screw and the stopper advance toward distal end **36** of the vial and administer the substance to the subject from the vial.

In some embodiments (as shown in FIG. 11), the distal end of the second threaded element is disposed inside stopper **24**. Although FIG. 11 shows the distal end of a screw disposed

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inside the stopper, the scope of the present application includes having the distal end of any embodiment of the second threaded element disposed inside stopper 24, in accordance with any of the methods or apparatus described herein. For example, the second threaded element may be a nut, e.g., as shown in FIGS. 6A-D, the distal end of the nut being disposed inside the stopper instead of being coupled to the proximal end of the stopper, as shown in FIGS. 6A-D. Typically, using a second threaded element that is disposed inside the stopper facilitates the use of a vial having a shorter length than would be necessary if the second threaded element was not disposed inside the stopper.

Reference is now made to FIGS. 12A-B, which are schematic illustrations of vial 22 containing a telescopic screw 150, in accordance with an embodiment of the present invention. Vial 22 of FIG. 12 is generally similar to vial 22 described with reference to FIG. 11, except for differences described hereinbelow.

In some embodiments, the second threaded element is a telescopic screw. First threaded element, by rotating, extends the telescopic screw and advances stopper 24 and distal end 152 of the telescopic screw toward distal end 36 of vial 22, in accordance with the techniques described hereinabove. In some embodiments, using a telescopic screw as the second threaded element facilitates the use of a smaller length vial to administer a given amount of the substance than would be necessary if a non-telescopic screw, or a nut were used as the second threaded element. In some embodiments, a telescopic screw is used as the first threaded element, and a nut is used as the second threaded element.

Although a telescopic screw having two overlapping portions 154 and 156 is shown, the scope of the present invention includes using a screw having more three or more overlapping portions as the second threaded element of vial 22. Typically, the ratio of the length of the telescopic screw when fully extended to the length of the telescopic screw when fully contracted (as shown in FIG. 12) is 1.5:1 to 2:1.

In some embodiments, as shown in FIG. 12B, a second threaded element (e.g., a nut or a screw) is used that is (a) telescopic, and (b) disposed at least partially inside stopper 24. For example, FIG. 12B shows a telescopic screw, a distal end of which is disposed inside stopper 24. Typically, using a second threaded element that is (a) telescopic, and (b) disposed at least partially inside stopper 24 facilitates the use of a shorter vial to administer a given amount of the substance than would otherwise be necessary, *ceteris paribus*.

Reference is now made to FIG. 13, which is a schematic illustration of vial 22 containing a telescopic nut 160, in accordance with an embodiment of the present invention. For some applications, a telescopic nut, such as that described in U.S. Pat. No. 6,905,298 to Haring, is used as the first threaded element (configuration not shown) or as the second threaded element (as shown) inside vial 22. In an embodiment, the nut is configured such that frictional forces between a first portion 164 and a second portion 166 of the nut prevent the first and second portion from becoming disengaged from each other. In addition, frictional forces between the screw and portion 166 prevent the screw and portion 166 from becoming disengaged. For example, the threads at the distal portion of the screw and on the inner surface of the proximal portion of portion 166 may widen, such that portion 166 cannot be unscrewed from the screw.

Vial 22 of FIG. 13 is generally similar to vial 22 described with reference to FIG. 12, except that a telescopic nut, instead of a telescopic screw, is used as the second threaded element. Although a telescopic nut having two overlapping portions 164 and 166 is shown, the scope of the present invention

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includes using a nut having three or more overlapping portions as the second threaded element of vial 22. Typically, the ratio of the length of the telescopic nut when fully extended to the length of the telescopic nut when fully contracted (as shown in FIG. 13) is 1.5:1 to 2:1.

Reference is now made to FIG. 14, which is a schematic illustration of apparatus 20 including a vial housing unit 170 and a separate needle housing unit 172, in accordance with an embodiment of the present invention. The apparatus shown in FIG. 14 is generally similar to the apparatus shown in FIGS. 1 and 2, except for the differences described hereinbelow.

In some embodiments, activation mechanism 56 is housed in needle housing unit 172. The activation mechanism, as described hereinabove, inserts cannula 100 and/or needle 102 through the subject's skin and delivers the substance via the cannula and/or the needle. Vial 22 and control components, such as motor 50 and battery 58, are housed separately in vial housing unit 170. In some embodiments, needle housing unit 172 is adhered to the subject's skin, and vial housing unit 170 is not adhered to the subject's skin. Typically, the needle housing unit and the vial housing unit are not rigidly connected to each other. For example, vial housing unit 170 may be worn on the subject's belt, or elsewhere on the subject's clothing. Typically, vial housing unit 170 is coupled to needle housing unit 172 via tube 53, via which the substance flows from the vial toward activation mechanism 56.

It is noted that, although a specific configuration of activation mechanism 56 is shown, in some embodiments, needle housing unit 172 houses an activation mechanism having a different configuration. For example, needle housing unit 172 may house only cannula 100 and/or needle 102. The subject inserts the needle into the subject's skin by adhering the needle housing unit to the skin.

It will be appreciated by persons skilled in the art that the present invention is not limited to what has been particularly shown and described hereinabove. Rather, the scope of the present invention includes both combinations and subcombinations of the various features described hereinabove, as well as variations and modifications thereof that are not in the prior art, which would occur to persons skilled in the art upon reading the foregoing description.

The invention claimed is:

1. An apparatus for administering a substance to a subject, comprising:

- a housing base;
 - a vial, containing the substance, inserted into the housing base, the vial having an inner cylindrical surface;
 - a stopper within the vial, slidably coupled to the vial and being in sliding frictional contact with the inner cylindrical surface, said frictional contact including a rotational friction component for precluding rotation of said stopper relative to said vial and a linear friction component for precluding linear advancement of said stopper in a distal direction;
 - a first threaded element (a) rotatable with respect to the vial and (b) substantially immobile linearly with respect to the vial during rotation of the first threaded element; and
 - a second threaded element that is threadedly coupled to the first threaded element forming a threaded coupling between the first threaded element and the second threaded element,
- the threaded coupling being within the vial,
- distal end of the second threaded element defining a coupling portion that couples the second threaded element to the stopper,
- the arrangement being such that the first threaded element, by rotating, overcomes said linear friction component

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for linearly advancing the second threaded element and the stopper toward a distal end of the vial, wherein the rotational friction component between the stopper and the inner cylindrical surface substantially impedes rotation of the stopper and the second threaded element relative to the first threaded element, and wherein a portion of the housing base is configured to displace the first and second threaded elements and the stopper toward the distal end of the vial during the insertion into the housing base.

2. The apparatus according to claim 1, wherein the vial and the first and second threaded elements are configured to be inserted into the housing base and further comprising, a needle coupled to the housing base and a cannula at least partially disposed around the needle, wherein the needle is configured to pierce skin of the subject and insert the cannula into the subject's skin, wherein the needle is configured to retract subsequent to piercing, and wherein the apparatus is configured to administer the substance to the subject via the cannula.

3. The apparatus according to claim 2, further comprising a needle activation mechanism coupled to the needle, the needle activation mechanism comprising: a subject-contact surface for application thereto of a force by the subject; and a force-receiving element which is configured to be displaced when the force applied by the subject to the subject-contact surface exceeds a threshold force, wherein the needle is configured to rapidly pierce the skin in response to displacement of the force-receiving element due to the force exceeding the threshold force.

4. The apparatus according to claim 3, further comprising a spring configured to retract the needle subsequent to the piercing.

5. The apparatus according to claim 1, further comprising:
a vial housing unit that houses the vial and the first and second threaded elements;
a needle housing unit coupled to the vial housing unit and not rigidly connected to the housing unit;
a needle housed within the needle housing unit; and
a cannula at least partially disposed around the needle, wherein the apparatus is configured to administer the substance to the subject via the cannula.

6. The apparatus according to claim 5, wherein during insertion of the vial into the vial housing unit, the first and second threaded elements and the stopper are displaced toward the distal end of the vial.

7. The apparatus according to claim 1, wherein the first threaded element comprises a nut, and wherein the second threaded element comprises a screw disposed at least partially inside the nut.

8. The apparatus according to claim 7, wherein the screw comprises a telescopic screw, and wherein the nut is configured to advance a distal end of the screw toward the distal end of the vial by extending the telescopic screw toward the distal end of the vial.

9. The apparatus according to claim 1, further comprising a cannula coupled to the housing base and configured to be inserted into skin of the subject, wherein the housing base, by displacing the first and second threaded elements and the stopper, is configured to expel gas through a distal end of the cannula.

10. The apparatus according to claim 9, wherein the portion of the housing base, by displacing the first and second threaded elements and the stopper, is configured to expel at least some of the substance through the distal end of the cannula.

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11. The apparatus according to claim 1, wherein the portion of the housing base is disposed with respect to a portion at a proximal end of the vial such that, during the insertion of the vial and the first and second threaded elements into the housing base, relative motion between the portion of the housing base and the portion at the proximal end of the vial displaces the first and second threaded elements and the stopper toward the distal end of the vial.

12. The apparatus according to claim 11, wherein the portion of the housing base is disposed such that sliding motion between the portion of the housing base and the portion at the proximal end of the vial advances the first and second threaded elements and the stopper toward the distal end of the vial.

13. The apparatus according to claim 1, further comprising at least one microneedle coupled to the housing base and configured to pierce skin of the subject, and wherein the apparatus is configured to administer the substance to the subject via the at least one microneedle.

14. The apparatus according to claim 13, wherein a diameter of each microneedle is less than 150 microns.

15. The apparatus according to claim 1, wherein the distal end of the second threaded element is disposed at least partially within the stopper.

16. The apparatus according to claim 1, wherein the inner cylindrical surface is smooth.

17. The apparatus according to claim 1, wherein a distal end of the second threaded element is configured to remain proximal to a distal end of the stopper at all times during the rotating of the first threaded element.

18. The apparatus according to claim 1, wherein the first threaded element comprises a screw, and wherein the second threaded element comprises a nut disposed at least partially around the screw.

19. The apparatus according to claim 1, wherein a ratio of a maximal diameter to a pitch of said first threaded element is such that rotation of the stopper is impeded to a much greater extent than impediment of the linear advancement of the stopper by the pitch of the first and second threaded elements.

20. The apparatus according to claim 1, wherein the portion of the housing base is configured to apply a sufficient force, in displacing the first and second threaded elements and the stopper, to overcome friction between the stopper and the vial that is due to prolonged storage of the stopper in contact with the vial.

21. An apparatus for administering a substance to a subject, comprising:

- a housing base;
 - a vial, containing the substance, inserted into the housing base, the vial having an inner cylindrical surface;
 - a stopper within the vial, slidably coupled to the vial and being in sliding frictional contact with the inner cylindrical surface, said frictional contact including a rotational friction component for precluding rotation of said stopper relative to said vial and a linear friction component for precluding linear advancement of said stopper in a distal direction;
 - a first threaded element (a) rotatable with respect to the vial and (b) substantially immobile linearly with respect to the vial during rotation of the first threaded element; and
 - a second threaded element that is threadedly coupled to the first threaded element forming a threaded coupling between the first threaded element and the second threaded element,
- the threaded coupling being within the vial,
a distal end of the second threaded element remaining proximal to a distal end of the stopper at all times during

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rotation of the first threaded element, and the first threaded element, by rotating, overcoming said linear friction component for linearly advancing the second threaded element and the stopper toward a distal end of the vial, wherein the rotational friction component 5 between the stopper and the inner cylindrical surface substantially impedes rotation of the stopper and the second threaded element relative to the vial, and wherein a portion of the housing base is configured to displace the first and second threaded elements and the stopper 10 toward the distal end of the vial during the insertion into the housing base.

22. The apparatus according to claim **21**, wherein a ratio of a maximal diameter to a pitch of said first threaded element is such that rotation of the stopper is impeded to a much greater 15 extent than impediment of the linear advancement of the stopper by the pitch of the first and second threaded elements.

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